Chapter II

REVIEW OF RELATED LITERATURE

Capitalizing on the reviews of expert researchers would be fruitful in providing helpful ideas and suggestions. Keeping this in mind the researcher made an attempt to go through the related literatures available in the libraries of Department of Physical Education and Sports Sciences, Annamalai University, Chidambaram, Tamilnadu. The researcher reviewed the literature and research work, published so far here in India and abroad, on the allied field and physical education and sports. Extensive studies regarding aerobic training through 4 vs. 4 small sided games impact on physical fitness and physiological performance of handball players were reviewed. The relative studies found from various sources are cited below.

Physical fitness

Póvoas et al. (2012) aimed to analyze elite team handball players physical and physiological demands during match play. Time-motion (N = 30) and heart rate (HR; N = 60) analyses were performed throughout 10 official matches. The defined locomotor categories were standing still, walking, jogging, fast running, sprinting, backwards movement, sideways medium-intensity movement, and sideways high-
intensity movement, and playing actions studied were jumps, shots, stops when preceded by high-intensity activities, changes of direction and one-on-one situations. During matches, the mean distances covered were 4,370 ± 702.0 m. Around 80% of the total time was spent standing still (43.0 ± 9.27%) and walking (35.0 ± 6.94%) and only 0.4 ± 0.31% with sprinting. The most frequent high-intensity actions were stops, change of direction, and one-on-one situations. Effective mean HR was 157 ± 18.0 b·min⁻¹ (82 ± 9.3% of HRmax), and total HR was 139 ± 31.9 b·min⁻¹ (72 ± 16.7% of HRmax). The HR, time spent in high-intensity activities, frequency of stops, changes of direction, one-on-one situations, and most intense periods of the game were higher during the first half than during the second half (p ≤ 0.05). The opposite was observed for the number of time outs and the time between each change of activity (p = 0.00). Handball is an intermittent exercise that primarily uses aerobic metabolism, interspersed by high-intensity actions that greatly tax anaerobic metabolism. Additionally, exercise intensity decreases from the first to the second half of the match, suggesting that neuromuscular fatigue may occur during the game. The training of elite handball players should
comprise exercises targeting the ability to perform specific high-intensity actions throughout the game and to rapidly recover during the less intense periods.

Young and Rogers (2014) assessed the effects of training change-of-direction speed and small-sided games on performance in the Planned-AFL agility test and reactive agility. Twenty-five elite-standard U-18 Australian Rules football players were randomly allocated either to a change-of-direction group or a small-sided games group. Players participated in one or two 15-min sessions per week with 11 sessions conducted over a 7-week period during the season. Tests conducted immediately before and after the training period included the Planned-AFL agility test and a video-based reactive agility test specific to Australian Rules football. The reactive agility test variables were total time, decision time and movement response time. The small-sided games group improved total time (P = 0.008, effect size = 0.93), which was entirely attributable to a very large reduction in decision time (P < 0.001, effect size = 2.32). Small-sided games produced a trivial change in movement response time as well as in the Planned-AFL agility test (P > 0.05). The change-of-direction training produced small to trivial changes
in all of the test variables (P > 0.05, effect size = 0.0-0.2). Their results suggested that small-sided games improve agility performance by enhancing the speed of decision-making rather than movement speed. The change-of-direction training was not effective for developing either change-of-direction speed as measured by the Planned-AFL test or reactive agility.

**Chelly et al. (2011)** examined the activity profile of elite adolescent players during regular team handball games and to compare the physical and motor performance of players between the first and second halves of a match. Activity patterns (video analysis) and heart-rate (HR) responses (telemetry) were monitored in top national-division adolescent players (18 men, aged 15.1 ± 0.6 years) throughout 6 regulation games (25-minute halves with a 10-minute interval). The total distance covered averaged 1,777 ± 264 m per game (7.4% less in the second than in the first half, p > 0.05). Players ran 170 ± 24 m at high intensity and 86 ± 12 m at maximal speed, with 32 ± 6 bouts of running (duration 2.3 ± 0.3 seconds) at speeds > 18 km·h⁻¹; they stood still for 16% of the playing time. The mean HR during play was 172 ± 2 b·min⁻¹ (82 ± 3% of maximal HR). Blood lactate concentrations at the end of the first and second halves were
9.7 ± 1.1 and 8.3 ± 0.9 mmol·L⁻¹, respectively (difference p < 0.05). They concluded that adolescent handball players cover less distance and engage in fewer technical actions in the second half of a match. This indicates that team handball is physiologically very demanding. The practical implication is that coaches should seek to sustain performance in the second period of a game by modifying playing tactics and maximizing both aerobic and anaerobic fitness during the training sessions.

Owen et al. (2011) examined the difference in heart rate (HR) responses and technical activities placed upon European elite players when exposed to 2-sided games differing in the number of players and playing area. Fifteen male soccer players from a Scottish Premier League team (26.3 ± 4.85 years, 182.4 ± 6.99 cm, 79.5 ± 8.05 kg, VO₂max of 54.36 ± 5.45 ml·kg⁻¹·min⁻¹) performed both small (3 vs. 3 plus goalkeepers) and large (9 vs. 9 plus goalkeepers) sided games each lasting for 3 × 5 minutes interspersed with 4-minute passive recovery during the 2009-2010 season. The HR responses and players' technical actions were recorded throughout all sided games. Results show that small-sided games (SSG) induced significantly (p < 0.05, large effect)
higher HR responses as compared to large-sided games. Furthermore, during SSGs, players spent significantly longer time in the >85% maximal HR zone (p < 0.05, large effect) as compared to large-sided games. Technical analysis revealed a large practical difference (effect size ranged from 1.5 to 21.2) between small- and large-sided games: less number of blocks, headers, interceptions, passes, and receives but more dribbles, shots, and tackles in SSG. Furthermore, SSG induced significantly lesser total ball contacts per game (p < 0.05, large effect) but significantly greater ball contacts per individual (p < 0.05, large effect) when compared to larger-sided games. The different technical requirements also enable coaches to carry out training games more suitable to specific playing positions such as SSG for midfielders (more dribbles, tackles, and ball contacts per player) strikers (more shots), and large-sided games for defender (more blocks, headers, and interceptions).

Seitz et al. (2014) determined the effects of a small-sided game training intervention on the intermittent shuttle running performance, speed, and repeated sprint ability of elite rugby league players during the competitive phase of a rugby league season. Ten elite rugby league players from a
Stobart Super League team academy underwent 2 small-sided game sessions per week over an 8-week period. Each session consisted of four 10-minute blocks of 1 small-sided game, interspersed with a 3-minute recovery. Changes in physical performance were assessed before and after the training intervention with an intermittent shuttle running test (30-15 Intermittent Fitness Test), speed tests (10-, 20-, and 40-m linear sprints) and a repeated sprint ability test (8 × 20-m linear sprint, departing every 20 seconds). Results showed that the 30-15 Intermittent Fitness Test (+1.29%), 10-m (−3.17%), 20-m (−1.37%), and 40-m (−0.96%) sprint times and mean sprint time (−2.11%), total sprint time (−2.11%), and percentage of sprint decrement (7.10 vs. 5.93%) during the repeated sprint ability test were significantly improved after the training intervention. Based on the results, they concluded that an 8-week small-sided game training intervention was an effective method for improving the physical performance of elite rugby league players during the competitive phase of the season.

Trajković et al. (2012) determined the changes in physical performance after a 6-week skill-based conditioning training program in male competitive volleyball players.
Sixteen male volleyball players (mean ± SD: age 22.3 ± 3.7 years, body height 190.7 ± 4.2 cm, and body mass 78.4 ± 4.5 kg) participated in this study. The players were tested for sprinting (5- and 10-m sprint), agility, and jumping performance (the vertical-jump test, the spike-jump test, and the standing broad jump [SBJ]). Compared with pretraining, there was a significant improvement in the 5- and 10-m speed. There were no significant differences between pretraining and posttraining for lower-body muscular power (vertical-jump height, spike-jump height, and SBJ) and agility. Based on the results, they concluded that a preseason skill-based conditioning program does not offer sufficient stimulus for volleyball players. Therefore, a general conditioning and hypertrophy training along with specific volleyball conditioning is necessary in the preseason period for the development of the lower-body strength, agility and speed performance in volleyball players.

**Ingebrigtsen et al. (2013)** investigated the performance effects of a 6-week biweekly anaerobic speed endurance production training among junior elite soccer players. Sixteen junior (age 16.9 ± 0.6 years) elite soccer players were tested in the Yo-Yo Intermittent Recovery test level 2 (IR2), 10-m and
35-m sprints, 7 × 35-m repeated-sprint ability (RSA) tests, countermovement jump and squat jump tests, and randomly assigned to either a control group (CG) performing their normal training schedule, which included 4 weekly soccer training sessions of approximately 90 minutes, or a training group performing anaerobic speed endurance production training twice weekly for 6 weeks in addition to their normal weekly schedule. They found that the intervention group significantly improved (p < 0.05) their performance in the Yo-Yo IR2 (63 ± 74 m) and 10-m sprint time (−0.06 ± 0.06 seconds). No significant performance changes were found in the CG. Between-group pre test to post test differences were found for 10-m sprint times (p < 0.05). No significant changes were observed in the 35-m sprint times, RSA, or jump performances. Their results indicated that short-term anaerobic production training is effective in improving acceleration and intermittent exercise performance among well-trained junior elite players.

Casamichana, Castellano and Castagna (2012) compared the physical demands of friendly matches (FMs) and small-sided games (SGs) in semiprofessional soccer players by means of global positioning system technology.
Twenty-seven semi professional soccer players were monitored during 7 FMs and 9 sessions involving different SGs. Their physical profile was described on the basis of 20 variables related to distances and frequencies at different running speeds, the number of accelerations, and through global indicators of workload such as the work : rest ratio, player workload, and the exertion index. Results showed significant differences (p < 0.01) between SGs and FMs for the following variables: overall workload (SG > FM); the distribution of the distance covered in the speed zones 7.0-12.9 km·h(-1) (SG > FM) and >21 km·h(-1) (FM > SG); the distribution of time spent in certain speed zones (FM > SG: 0.0-6.9 and >21 km·h(-1); FM > SG: 7.0-12.9 km·h(-1)). More sprints per hour of play were performed during FMs, with greater mean durations and distances, greater maximum durations and distances, and a greater frequency per hour of play for sprints of 10-40 and >40 m (p < 0.01). The frequency of repeated high-intensity efforts was higher during FM (p < 0.01). Their results showed that coaches and strength and conditioning professionals should consider FMs during their training routine to foster specific adaptations in the domain of high-intensity effort.
Brandes, Heitmann and Müller (2012) have stated that a major use of small-sided games (SSGs) in soccer training is the concomitant development of game-specific aerobic fitness. They hypothesized that the SSG formats of 2 vs. 2, 3 vs. 3, and 4 vs. 4 players reveal game-like intensities and therefore are most adequate to increase game-specific aerobic fitness. Heart rate (HR), percentage of maximum heart rate (HRmax), blood lactate concentration (La), and time-motion characteristics of 17 elite male youth soccer players (aged 14.9 ± 0.7 years, VO$_2$max 61.4 ± 4.5 ml·kg·min, HRmax 199.6 ± 7.3 b·min) were collected by global positioning systems while performing the SSG formats. Repeated-measures analysis of variance and effect sizes were calculated to demonstrate the differences between SSG formats. Highest physiological responses were obtained in 2 vs. 2 (HR: 186 ± 7 b·min, HRmax: 93.3 ± 4.2%, La: 5.5 ± 2.4 mmol·L) followed by 3 vs. 3 (HR: 184 ± 8 b·min, HRmax: 91.5 ± 3.3%, La: 4.3 ± 1.7 mmol·L) and 4 vs. 4 (HR: 179 ± 7 b·min, HRmax 89.7 ± 3.4%, La: 4.4 ± 1.9 mmol·L). Pronounced differences were found for most physiological parameters and for time spent in the speed zones "walking" (<5.3 km·h), "moderate-speed running" (10.3-13.9 km·h), and "maximum sprinting" (≥26.8 km·h). Their
findings suggested that all the formats reveal game-like intensities and are suitable for aerobic fitness improvements. However, they found pronounced demands on the anaerobic energy supply in 2 vs. 2, whereas 3 vs. 3 and 4 vs. 4 remain predominantly on an aerobic level and differ mainly in the HR response. They suggested using 3 vs. 3 for soccer-specific aerobic fitness training.

**Buchheit et al. (2009)** compared the effect of high-intensity interval training (HIT) versus specific game-based handball training (HBT) on handball performance parameters. Thirty-two highly-trained adolescents (15.5±/-0.9 y) were assigned to either HIT (n=17) or HBT (n=15) groups, that performed either HIT or HBT twice per week for 10 weeks. The HIT consisted of 12-24 x 15 seconds runs at 95% of the speed reached at the end of the 30-15 Intermittent Fitness Test (V(IFT)) interspersed with 15 s passive recovery, while the HBT consisted of small-sided handball games performed over a similar time period. Before and after training, performance was assessed with a counter movement jump (CMJ), 10 m sprint time (10 m), best (RSAbest) and mean (RSAmean) times on a repeated sprint ability (RSA) test, the V(IFT) and the intermittent endurance index (iEI). After training, RSAbest (-
3.5+/−2.7%), RSAmean (−3.9+/−2.2%) and V(IFT) (+6.3+/−5.2%) were improved (P<0.05), but there was no difference between groups. They concluded that both HIT and HBT were found to be effective training modes for adolescent handball players. However, HBT should be considered as the preferred training method due to its higher game-based specificity.

Katis and Kellis (2009) first examined the movement actions performed during two different small-sided games and, second, their effects on a series of field endurance and technical tests. Thirty-four young soccer players (age: 13 ± 0.9 yrs; body mass: 62.3 ± 15.1 kg; height: 1.65 ± 0.06 m) participated in the study. Small-sided games included three-a-side (3 versus 3 players) and six-a-side (6 versus 6 players) games consisting of 10 bouts of 4 min duration with 3 min active recovery between bouts. Soccer player performance was evaluated using five field tests: a) 30m sprint, b) throw-in for distance, c) Illinois Agility Test, d) dribbling the ball and e) horizontal jump before, in the middle and after the implementation of both game situations. Heart rate was monitored during the entire testing session. Each game was also filmed to measure soccer movements within the game. The ANOVA analysis indicated that the three-a-side games
displayed significantly higher heart rate values compared with the six-a-side games (p < 0.05). The number of short passes, kicks, tackles, dribbles and scoring goals were significantly higher during the three-a-side compared with the six-a-side game condition (p < 0.05) while players performed more long passes and headed the ball more often during the six-a-side (p < 0.05). After the three-a-side games, there was a significant decline in sprint and agility performance (p < 0.05), while after both game conditions significant alterations in the throw-in and the horizontal jump performance were observed (p < 0.05). Their results showed that three-a-side games provide higher stimulus for physical conditioning and technical improvement than six-a-side games and their use for training young soccer players is recommended.

**Dellal et al. (2011)** examined the relationship between the playing level in soccer (i.e., amateur vs. professional players) and the physiological impact, perceptual responses, time-motion characteristics, and technical activities during various small-sided games (SSGs). Twenty international players (27.4 ± 1.5 years and 17.4 ± 0.8 km·h(-1) of vVO(2)max) and 20 amateur players of the fourth French division (26.3 ± 2.2 years and 17.0 ± 1.2 km·h(-1) of
vVO(2)max) played 9 SSGs (i.e., 2 vs. 2, 3 vs. 3, and 4 vs. 4) in which the number of ball touches authorized by possession varied (1 ball touch authorized = 1T, 2 ball touches authorized = 2T, and Free Play = FP). Heart rate (HR), blood lactate ([La]), subjective perception of effort (rating of perceived exertion [RPE]), physical performance, and technical performance of all the players were analyzed during all SSGs. Across the various SSGs, amateurs completed a lower percent of successful passes (p < 0.01), recorded higher RPE and [La] values, lost a greater amount of ball possessions (p < 0.001), and covered less total distance with respect to sprinting and high-intensity running (HIR). The HR responses, however, were similar when expressed as %HRmax and %HRreserve. The comparison of the professional and amateur soccer players' activities during SSGs showed that the playing level influenced the physiological responses, physical and technical activities. Consequently, their study has shown that the main differences between elite and amateur players within SSGs concerned their capacity to perform high-intensity actions (HIR and sprints) and execute various technical abilities (in particular number of ball lost per possession and percentage of successful passes).
Los Arcos et al. (2014) compared the effects of 2 strength and conditioning programs involving either purely vertically oriented or combining vertically and horizontally oriented exercises on soccer-relevant performance variables (ie, acceleration, jumping ability, peak power, and endurance). Twenty-two professional male soccer players were randomly assigned to 2 training groups: vertical strength (VS, n = 11) and vertical and horizontal strength (VHS, n = 11). Players trained 2 times per week during all the preseason (5 wk) and 3 weeks during the competitive season. The effect of the training protocols was assessed using double-and single-leg vertical countermovement jumps (CMJ), half-squat peak power (PP), sprint performance over 5 and 15 m, and blood lactate concentration at selected running speeds. Their result showed that both groups obtained significant improvements in PP (P < .05; ES = 0.87 and 0.80 for VS and VHS, respectively) and small practical improvements in 5-m- (P < .05; ES = 0.27 and 0.25 for VS and VHS, respectively) and 15-m-sprint time (P < .05; ES = 0.19 and 0.24 for VS and VHS, respectively). The CMJ performance showed a small improvement (P < .05, ES = 0.34) only in the VHS group. Submaximal aerobic-fitness changes were similar in both
groups (P < .05; ES = 1.89 and 0.71 for VS and VHS, respectively). Their study provided a small amount of practical evidence for the consideration of preseason training protocols that combine exercises for vertical- and horizontal-axis strength development in professional male soccer players.

Gaudino et al. (2014) at first evaluated the agreement between estimates of high-intensity activity during soccer small-sided games (SSGs) based on running speed alone and estimated metabolic power derived from a combination of running speed and acceleration and the second evaluated as to whether any bias between the 2 approaches is dependent upon playing position or drill characteristics. 3 types of SSGs (5vs5, 7vs7 and 10vs10) were completed by 26 English Premier League outfield players. A total of 420 individual drill observations were collected over the in-season period using portable global positioning system technology. High-intensity activity was estimated using the total distance covered at speeds > 14.4 km/h (TS) and the equivalent metabolic power threshold of > 20 W/kg (TP). They selected 0.2 as the minimally important standardised difference between methods. High-intensity demands were systematically higher (~100%, p<0.001) when expressed as TP vs. TS irrespective of
playing position and SSG. The magnitude of this difference increased as the size of SSG decreased (p<0.01) with a difference of ~200% observed in the 5vs5 SSG. A greater difference between TP and TS was also evident in central defenders compared to other positions (p<0.05) particularly during the 5vs5 SSG (~350%). They concluded that the high-intensity demands of SSGs in elite soccer players are systematically underestimated by running speed alone particularly during "small" SSGs and especially for central defenders. Estimations of metabolic power provide a more valid estimation as to the true demands of SSGs.

Owen et al. (2012) examined the effects of periodized small-sided game (SSG) training intervention during a 4-week in-season break on the physical performance changes (i.e., speed, aerobic performance, and repeated sprint ability) within elite European soccer players. Fifteen, elite, male, professional players (age: 24.5 ± 3.45 years; height: 181.1 ± 5.78 cm; body mass: 78.7 ± 7.67 kg; VO2max: 54.88 ± 5.25 ml·kg(-1)·min(-1)) from a Scottish Premier League team participated in 7 separate SSG sessions (3 vs. 3 plus goalkeepers) of which games lasted for a 3-minute duration for the selected number of games (ranged from 5 to 11)
increasing over the intervention period. To examine the effects of the SSG intervention on physical performance changes, pre- and post testing sessions took place over a 2-day period (day 1: anthropometry and repeated sprint ability [RSA] assessments; day 2: running economy [RE] and blood lactate assessments). Their results showed that the 4-week SSG training intervention induced significant improvement in RSA as indicated by faster 10-m sprint time (p < 0.05, small effect), total sprint time (p < 0.05, medium effect), and smaller percentage decrement score (p < 0.05, medium effect). Furthermore, the SSGs also led to an improvement in RE as indicated through significantly reduced VO₂ and heart rate at running speed 9, 11, and 14 km·h⁻¹ (all p's < 0.05, large effects). Their study demonstrated the effect of implementing a periodized SSG training intervention during the 4-week in-season break is capable of improving elite-level soccer players' physical fitness characteristics. Being able to develop physical characteristics in conjunction to technical and tactical elements of the game, within a relatively short period, makes SSGs an appealing proposition for fitness coaches, players, and technical coaches alike.
Gabbett (2006) investigated the effects of skill-based conditioning games and traditional conditioning for improving speed, agility, muscular power, and maximal aerobic power in rugby league players. Sixty-nine sub elite rugby league players performed either a skill-based conditioning games program (N = 32) or a traditional conditioning (i.e., running activities with no skill component) program (N = 37). Each player participated in a 9-week in-season training program, performed over 2 competitive seasons. Players performed 2 organized field-training sessions each week. Players underwent measurements of speed (10-m, 20-m, and 40-m sprint), muscular power (vertical jump), agility (L run), and maximal aerobic power (multi-stage fitness test) before and after the training period. Skill-based conditioning games induced a significant improvement (p < 0.05) in 10-m, 20-m, and 40-m speed, muscular power, and maximal aerobic power, whereas traditional conditioning activities improved 10-m speed and maximal aerobic power only. No significant differences (p > 0.05) were detected between the traditional conditioning and skill-based conditioning games groups for changes in 10-m speed, agility, and maximal aerobic power. Both groups won 6 of 8 matches played within the training
period, resulting in a win-loss ratio of 75%. However, on average, the skill-based conditioning games group scored more points in attack (p < 0.05) and had a greater (p < 0.05) points differential than the traditional conditioning group. Their results demonstrated that skill-based conditioning games offer an effective method of in-season conditioning for rugby league players. In addition, given that skills learned from skill-based conditioning games are more likely to be applied in the competitive environment, their use may provide a practical alternative to traditional conditioning for improving the physiological capacities and playing performance of rugby league players.

McMillan et al. (2005) aimed to study the physiological adaptations to a 10 week high intensity aerobic interval training program performed by professional youth soccer players, using a soccer specific ball dribbling track. Eleven youth soccer players with a mean (SD) age of 16.9 (0.4) years performed high intensity aerobic interval training sessions twice per week for 10 weeks in addition to normal soccer training. The specific aerobic training consisted of four sets of 4 min work periods dribbling a soccer ball around a specially designed track at 90–95% of maximal heart frequency, with a
3 min recovery jog at 70% of maximal heart frequency between intervals. Their result showed mean VO\textsubscript{2max} improved significantly from 63.4(5.6) to 69.8(6.6) ml/kg/min, or 183.3(13.2) to 201.5(16.2) ml/kg/min (p = 0.001). Squat jump and counter movement jump height increased significantly from 37.7 (6.2) to 40.3 (6.1) cm and 52.0 (4.0) to 53.4 (4.2) cm, respectively (p < 0.05). No significant changes in body mass, running economy, rate of force development, or 10 m sprint times occurred. They concluded that performing high intensity 4 min intervals dribbling a soccer ball around a specially designed track together with regular soccer training is effective for improving the VO\textsubscript{2max} of soccer players, with no negative interference effects on strength, jumping ability, and sprinting performance.

**Physiological variables**

*Sotiropoulos et al. (2009)* evaluated the changes in body fat percentage and aerobic capacity in professional soccer players, after the implementation of a specific 4-week training regimen during the transition period. Fifty-eight professional soccer players of the Greek Premier National Division were separated in experimental (n = 38) and control groups (n = 20). Body composition and maximum oxygen
intake were evaluated before and after a 4-week training regimen followed during the transition period. The experimental design used for analyzing weight (kg), percent body fat (%) and VO₂ max values (ml·kg⁻¹·min⁻¹) was a 2 × 2 (Groups × Measures), with Groups as between-subjects factor and Measures as within-subjects factor. The level of significance was set at p ≤ 0.05 for all analysis. Analysis of variance showed that the experimental and the control groups achieved statistically significant (a) increases from pre test to post test measures in body weight (0.595 kg and 1.425 kg, respectively) and percent body fat (0.25 and 0.82, respectively), and (b) decreases in VO₂ max values from pretest to posttest measures (0.81 and 3.56, respectively). Their findings of the study revealed that the players who followed the training regimen compared with the players who did not follow any specific training program gained less weight and body fat and exhibited lower reduction in their VO₂ max values.

_Bekris et al. (2014)_ has stated that soccer is a demanding physical game which requires resistance on fatigue so as to improve the performance. The mechanisms which relate the fatigue and the performance (i.e. cognitive,
physiological, physical, and technical factors) are described to the current study. Nowadays the small-sided games (SSG) are considered as the main method of increasing the physical condition, however there is a literature gap on the mechanisms that contribute to this relationship. Consequently, the aim of their study was to examine how the 3vs3 SSG affect the fatigue and how training either above or under the anaerobic threshold (AT) influence it differently. Six semi-professional male soccer players (age 17.4±0.5 years, height 1.70±0.14 m, body mass 65.0±4.8 kg), participated in the study. Anaerobic threshold, maximal oxygen uptake (VO$_2$max), and the maximal heart rate (HRmax) of each player on the treadmill were measured. The researchers also examined the heart rate, blood lactic acid, visual reaction, juggling and maximal ball speed during shooting of every player. The statistical analysis that was used was descriptive statistics and pairwise comparisons. The results revealed the relationships between fatigue and technical skills (i.e. anaerobic threshold and maximal ball speed during shooting). Specifically, it was found that players who practiced above AT presented a stronger reduction of the maximal ball speed during shooting.
Ade, Harley & Bradley (2014) tried to quantify the physiological responses, time-motion characteristics, and reproducibility of various speed-endurance-production (SEP) and speed-endurance-maintenance (SEM) drills. They selected sixteen elite male youth soccer players completed 4 drills: SEP 1 v 1 small-sided game (SSG), SEP running drill, SEM 2 v 2 SSG, and SEM running drill. Heart-rate response, blood lactate concentration, subjective rating of perceived exertion (RPE), and time-motion characteristics were recorded for each drill. The SEP and SEM running drills elicited greater (P < .05) heart-rate responses, blood lactate concentrations, and RPE than the respective SSGs (ES 1.1-1.4 and 1.0-3.2). Players covered less (P < .01) total distance and high-intensity distance in the SEP and SEM SSGs than in the respective running drills (ES 6.0-22.1 and 3.0-18.4). Greater distances (P < .01) were covered in high to maximum acceleration/deceleration bands during the SEP and SEM SSGs than the respective running drills (ES 2.6-4.6 and 2.3-4.8). The SEP SSG and generic running protocols produced greater (P < .05) blood lactate concentrations than the respective SEM protocols (ES 1.2-1.7). Small to moderate test-retest variability was observed for heart-rate response (CV
0.9-1.9%), RPE (CV 2.9-5.7%), and blood lactate concentration (CV 9.9-14.4%); moderate to large test-retest variability was observed for high-intensity-running parameters (CV > 11.3%) and the majority of accelerations/deceleration distances (CV > 9.8%) for each drill. They concluded that the data demonstrate the potential to tax the anaerobic energy system to different extents using speed-endurance SSGs and that SSGs elicit greater acceleration/deceleration load than generic running drills.

Köklü (2012) investigated physiological responses to various intermittent and continuous small-sided games (SSGs) - including 2-a-side, 3-a-side, and 4-a-side games - in young soccer players. Twenty soccer players (average age 16.6±0.5 years; mean body height 176.2±4.6 cm; mean body mass 65.9±5.6 kg) voluntarily participated in this study. The subjects underwent anthropometric measurements followed by the YoYo intermittent recovery test. Then, they played intermittent (SSGint) and continuous (SSGcon) 2-a-side, 3-a-side, and 4-a-side soccer-specific SSGs in random order at 2-day intervals. Paired t-tests were used to assess differences between the training regimens (intermittent and continuous) in terms of heart rate (HR), percentage of maximum HR
(%HRmax), and blood lactate concentration (LA). The differences in LA, HR and %HRmax between the 2-a-side, 3-a-side and 4-a-side SSGint or the 2-a-side, 3-a-side and 4-a-side SSGcon were identified using one-way analysis of variance with repeated measures. The results demonstrated that the 3-a-side SSGint and SSGcon measurements were significantly higher than the 2-a-side and 4-a-side games in terms of HR and %HRmax, whereas the 2-a-side SSGint and SSGcon resulted in higher LA responses compared to other SSG types. Their study also demonstrated that SSGint and SSGcon are similar in terms of physiological responses except for 2-a-side game LA responses. The results of this study suggest that both SSGint and SSGcon could be used for the physiological adaptations required for soccer specific aerobic endurance.

Kelly, Gregson, Reilly & Drust (2013) stated that the use of sports-specific technical practices as a physical training stimulus has increased in recent years in soccer. Such approaches, although effective, can produce different levels of physiological strain in the individual players within the session, thereby limiting the usefulness of the training session for all players. The aim of their study was to develop a
A high-intensity soccer-specific training (SST) drill that was based not only on the demands of match-play but also to reduce the variability in the physiological response to training compared with other specific drills. To evaluate this approach to training, the SST drill was compared with a "traditional" aerobic interval training (AIT) protocol and a small-sided games (SSG) drill. Each training protocol was carried out across 4 × 4-minute exercise bouts, interspersed by 4 × 3 minutes of active recovery. Mean ± SD heart rates (HRs) for the 4-minute exercise bouts during SST (175 ± 5 b·min) and AIT (174 ± 6 b·min) were significantly higher than that observed during the SSG protocol (170 ± 6 b·min; p < 0.05). Heart rate during the SST drill showed less interparticipant variability (mean ± SD HR ranged from 169 ± 6 to 180 ± 5 b·min) when compared with those during AIT (157 ± 8 to 186 ± 8 b·min) and SSG (143 ± 10 to 179 ± 78 b·min) training conditions. Ratings of perceived exertion (SST, 6 ± 2; AIT, 7 ± 1; SSG, 5 ± 1) across the entire exercise period were similar between the 3 training conditions (p > 0.05). Their results indicated that the SST stimulates a more uniform physiological response than other currently adopted specific endurance training protocols used in soccer. This would
suggest that it provides a valid alternative to the current approaches used for the aerobic training of players.

Foster et al. (2010) investigated the influences of player number and playing area size on the heart rate (HR) responses elicited by junior male rugby league players during small-sided games (SSGs). Twenty-two players from a professional club (n = 22, mean age: 14.5 +/- 1.5 years; stature: 172.5 +/- 11.4 cm; body mass: 67.8 +/- 15.1 kg; Vo2peak: 53.3 +/- 5.6 mL.kg.min; HRmax: 198 +/- 7.8 beats.min) participated in 2 repeated trials of six 4-minute conditioned SSGs over a 2-week period. The SSGs varied by playing area size-15 x 25 m, 20 x 30 m, and 25 x 35 m-and player number-4v4 and 6v6. HRs were recorded continuously in each game and expressed as overall and age-related (15-16 and 12-13 years) means and percent of maximum (%HRmax). Analysis revealed a non significant (p > 0.05) effects of trials and playing area size on HRs but a significant effect of player number in the 15-16 age group only (p < 0.001), with HRs being higher in the 4v4 (90.6% HRmax) than the 6v6 SSGs (86.2% HRmax). The HR responses were found to be repeatable in all SSG conditions (within +/- 1.9% HRmax), apart from the small 6v6 condition in the older players. Their
findings demonstrated that these SSGs generate physiological responses suitable for aerobic conditioning that, although unaffected by the size of the area used, are sensitive to the player number. Accordingly, among such players it is advisable that coaches use 4v4 SSGs to achieve an appropriate and consistent aerobic conditioning stimulus.

Dellal et al. (2008) compared heart rate (HR) responses within and between physical controlled (short-duration intermittent running) and physical integrated (sided games) training methods in elite soccer players. Ten adult male elite soccer players (age, 26 +/- 2.9 years; body mass, 78.3 +/- 4.4 kg; maximum HR [HRmax], 195.4 +/- 4.9 b x min(-1) and velocity at maximal aerobic speed (MAS), 17.1 +/- 0.8 km x h(-1)) performed different short-duration intermittent runs, e.g., 30-30 (30 seconds of exercise interspersed with 30 seconds of recovery) with active recovery, and 30-30, 15-15, 10-10, and 5-20 seconds with passive recovery, and different sided games (1 versus 1, 2 versus 2, 4 versus 4, 8 versus 8 with and without a goalkeeper, and 10 versus 10). In both training methods, HR was measured and expressed as a mean percentage of HR reserve (%HRres). The %HRres in the 30-30-second intermittent run at 100% MAS with active
recovery (at 9 km.h with corresponding distance) was significantly higher than that with passive recovery (85.7% versus 77.2% HRres, respectively, p < 0.001) but also higher than the 1 versus 1 (p < 0.01), 4 versus 4 (p < or= 0.05), 8 versus 8 (p < 0.001), and 10 versus 10 (p < 0.01) small-sided games. The %HRres was 2-fold less homogeneous during the different small-sided games than during the short-duration intermittent running (intersubjects coefficient of variation [CV] = 11.8% versus 5.9%, respectively). During the 8 versus 8 sided game, the presence of goalkeepers induced an approximately 11% increase in %HRres and reduced homogeneity when compared to games without goalkeepers (intersubject CV = 15.6% versus 8.8%). In conclusion, their findings showed that some small-sided games allow the HR to increase to the same level as that in short-duration intermittent running. The sided game method can be used to bring more variety during training by mixing physical, technical, and tactical training approaching the intensity of short-duration intermittent running but with higher intersubject variability.

Mallo and Navarro (2008) examined the kinematical, physiological and technical load imposed on soccer players
during three typical small-sided 3-a-side training games carried out in an artificial grass 33x20 m surface. Kinematic analysis was carried out with a bi-dimensional photogrammetric video system. Heart rate was recorded at 5 s intervals using Polar Accurex Plus heart rate monitors and expressed in relation to individual maximal heart rate (HR(max)). The technical parameters were registered using a specifically designed notation sheet. Their result showed that the overall intensity of these three small-sided games was superior than the experienced during competitive matches. Distance covered (747-749 vs 638 m) and mean heart rate (173 vs 166 b x min(-1)) were higher (P<0.05) in the drills without goalkeepers. The inclusion of goalkeepers reduced the tempo of the game as players performed less (P<0.05) high-intensity running and increased (P<0.05) low-intensity activities. Time spent exercising at intensities between 76-85% HR(max) was lower (P<0.05) in the game without goalkeepers whereas the presence of goalkeepers reduced (P<0.05) the activities performed exceeding 86% HR(max). Their results suggested that small-sided games can be used effectively to develop the specific endurance capacity of football players. The integration of these drills by coaches
during the regular training schedule can help replicating the demands experienced during real match-play.

Impellizzeri et al. (2006) compared the effects of specific (small-sided games) vs. generic (running) aerobic interval training on physical fitness and objective measures of match performance in soccer. Forty junior players were randomly assigned to either generic (n=20) or specific (n=20) interval training consisting of 4 bouts of 4 min at 90-95 % of maximum heart rate with 3 min active rest periods, completed twice a week. The following outcomes were measured at baseline (Pre), after 4 weeks of pre-season training (Mid), and after a further 8 weeks of training during the regular season (Post): maximum oxygen uptake, lactate threshold (Tlac), running economy at Tlac, a soccer-specific endurance test (Ekblom's circuit), and indices of physical performance during soccer matches (total distance and time spent standing, walking, and at low and high-intensity running speed). Training load, as quantified by heart rate and rating of perceived exertion, was recorded during all the training sessions and was similar between groups. There were significant improvements in aerobic fitness and match performance in both the groups of soccer players, especially
in response to the first 4 weeks of pre-season training. However, no significant differences between specific and generic aerobic interval training were found in any of the measured variables including soccer specific tests. Their results showed that both small-sided games and running are equally effective modes of aerobic interval training in junior soccer players.

Casamichana and Castellano (2010) examined the physical, physiological, and motor responses and perceived exertion during different soccer drills. In small-sided games, the individual playing area (∼ 275 m², ∼ 175 m², and ∼ 75 m²) was varied while the number of players per team was kept constant: 5 vs. 5 plus goalkeepers. Participants were ten male youth soccer players. Each session comprised three small-sided game formats, which lasted 8 min each with a 5-min passive rest period between them. A range of variables was recorded and analysed for the three drills performed over three training sessions: (a) physiological, (measured using Polar Team devices); (b) physical, (using GPS SPI elite devices); (c) perceived exertion, (rated using the CR-10 scale); and (d) motor response, (evaluated using an observational tool that was specially designed for this study). Significant
differences were observed for most of the variables studied. When the individual’s playing area was larger, the effective playing time, the physical (total distance covered; distances covered in low-intensity running, medium-intensity running, and high-intensity running; distance covered per minute; maximum speed; work-to-rest ratio; sprint frequency) and physiological workload (percent maximum heart rate; percent mean heart rate; time spent above 90% maximum heart rate), and the rating of perceived exertion were all higher, while certain motor behaviours were observed less frequently (interception, control and dribble, control and shoot, clearance, and putting the ball in play). Their results showed that the size of the pitch should be taken into account when planning training drills, as it influences the intensity of the task and the motor response of players.

Hill-Haas et al. (2010) examined the acute physiological responses and time-motion characteristics associated with 4 soccer-specific small-sided game (SSG) formats (3 vs. 4 players, 3 vs. 3 players + floater, 5 vs. 6 players, and 5 vs. 5 players + floater) and 4 rule changes in elite youth soccer players. Sixteen male youth soccer players (mean +/- SD: age = 15.6 +/- 0.8 years, stature = 170.8 +/-
6.6 cm, body mass = 67.5 +/- 6.2 kg, and 20-m shuttle run estimated VO2max = 57.4 +/- 3.7 ml/kg/min) participated in the study, in which heart rate (HR), rating of perceived exertion (RPE), blood lactate (La), and time-motion characteristics were recorded. The rule change requiring extra sprint running had a greater effect on the time-motion characteristics than all other rule modifications but no effect on acute %HRmax, La, and RPE. Rule changes had no effect on RPE. Fixed underload teams (i.e., lower number of players compared with the opponent team) recorded a significantly higher RPE compared with the fixed overload teams, although there were no differences in %HRmax and La. The major practical findings were that subtle changes in SSGs playing rules can influence the physiological, perceptual, and time-motion responses in young elite soccer players. Rules that are related to a team’s chances of scoring may improve player motivation and thereby increase training intensity during SSGs. There was no differences between fixed and variable formats in terms of physiological and perceptual responses, although both may provide useful technical-tactical training. Coaches should take care in designing different soccer SSGs.
as each rule or game format change may influence exercise intensity independently.

Köklü et al. (2013) investigated the effect of 'with goalkeeper' (SSG with) and 'without goalkeeper' (SSG without) conditions on players' physiological responses and time motion characteristics in small sided games. Sixteen young soccer players (age 16.5±1.5 years; height 175.5±5.2 cm; body mass 63.0±6.9 kg; training experience 6.3±1.3 years) participated in 2 different 2-a-side, 3-a-side and 4-a-side games: SSG with and SSG without. The players underwent anthropometric measurements (height and body mass) followed by the YoYo intermittent recovery test (level 1). Then they played 2-a-side, 3-a-side, and 4-a-side SSG with and SSG without soccer-specific SSGs in random order at 2-day intervals. Heart rate (HR) responses, and distance covered in different speed zones (walking (WLK, 0-6.9 km.h), low-intensity running (LIR, 7.0-12.9km.h), moderate-intensity running (MIR, 13.0-17.9 km.h) and high-intensity running (HIR, >18km.h)) were measured during the SSGs, whereas the Rating of Perceived Exertion (RPE) and Blood Lactate (La) were determined at the end of the last bout of each SSG. During the SSG without players showed higher %HR, La and
RPE (p<0.05), greater distance covered in LIR, MIR, HIR and total distance (p<0.05) compared to the SSG with during the 2-a-side, 3-a-side and 4-a-side games. Their results suggested that both SSG with and SSG without could be used for the physiological adaptations required for soccer specific aerobic endurance. However, if coaches aim for both higher physiological responses and greater distance covered in the intensity running zone from their teams, SSG without should be organized. In addition, their study also suggested that smaller format games (i.e. 2-a-side) may promote some anaerobic adaptations for youth soccer players.

**Hill-Haas et al. (2009)** examined the acute physiological responses and time-motion characteristics associated with three different small-sided soccer game formats in youth players. Sixteen male soccer players aged 16.3+/−0.6 years (mean+/−s) completed three variations of a small-sided game (i.e. 2 vs. 2, 4 vs. 4, and 6 vs. 6 players) in which heart rate, rating of perceived exertion (RPE), blood lactate concentration, and time-motion characteristics were recorded. The pitch size was altered to keep the relative pitch area per player consistent for each game format. The 2 vs. 2 games exhibited greater blood lactate, heart rate, and RPE
responses compared with 4 vs. 4 and 6 vs. 6 games (P<0.05). The players travelled less (P<0.05) distance at speeds of 0-7 km.h(-1) in the 4 vs. 4 compared with the 2 vs. 2 games (1128+/-10 m and 1176+/-8 m, respectively). Average maximal sprint distances above 18 km.h(-1) were lower (P<0.05) in 2 vs. 2 than in 4 vs. 4 and 6 vs. 6 games (11.5+/-3.9 m, 15.3+/-5.5 m, and 19.4+/-5.9 m, respectively), and in 4 vs. 4 compared with 6 vs. 6 games. Their results revealed that as the small-sided game formats decrease in size and relative pitch area remains constant, overall physiological and perceptual workload increases.

Kennett et al. (2012) stated that small-sided games (SSGs) have been suggested as a method for concurrently training the physical, technical and tactical capabilities of rugby union players. Therefore, it is important to understand how prescriptive variables such as player number and field size influence the training stimulus during rugby-specific SSGs. Twenty semi professional rugby union players participated in a series of SSGs of varying player numbers (4 vs. 4, 6 vs. 6, and 8 vs. 8) on small- (32 × 24 m) and large-sized fields (64 × 48 m). The physiological (blood lactate concentration and heart rate [HR]), perceptual (rating of
perceived exertion [RPE]), and time-motion demands were assessed for each different SSG format. There were significant differences between the 4 vs. 4, 6 vs. 6, and 8 vs. 8 SSG formats in mean speed (meters per minute), high-speed running (HSR) distance (metres), and RPE (all p < 0.05). Blood lactate was greater in 4 vs. 4 compared with that in 8 vs. 8 SSGs. The mean speed, HSR distance, number of sprints, peak speed, blood lactate concentration, and RPE were all significantly different between large and small-field size (all p < 0.05). There were no significant difference between game formats (4 vs. 4, 6 vs. 6, and 8 vs. 8) or field size (small or large) for either percent HRmax or time spent >85% HRmax. Their results showed that SSGs with fewer players and larger field sizes elicit greater physiological and perceptual responses and time-motion demands. In contrast, the HR response was similar between all SSG formats, which may be attributable to high levels of individual variability in the HR response. Their study provided new information about the influence of player number and field size on the training stimulus provided by rugby-specific SSGs.

Köklü et al (2012) examined the influence of different team formation methods on the physiological responses to
and time-motion characteristics of 4-a-side small-sided games (SSG4) in young soccer players. Thirty-two young soccer players (age 16.2 ± 0.7 years; height 172.9 ± 6.1 cm; body mass 64.1 ± 7.7 kg) voluntarily participated in this study. Anthropometric measurements, technical tests, and maximum oxygen uptake (VO\(_2\max\)) tests were carried out on the players. The SSG4 teams were then created using 4 different methods: according to the coaches' subjective evaluation (CE), technical scores (TS), VO\(_2\max\) (AP), and VO\(_2\max\) multiplied by TSs (CG). The teams thus created played 4 bouts of SSG4 at 2-day intervals. During the SSG4, heart rate (HR) responses, distance covered, and time spent in HR\(_\text{max}\) zones were recorded. In addition, rating of perceived exertion (RPE) and blood lactate level (La) were determined at the end of the last bout of each SSG4. Percent of HR\(_\text{max}\) (%HR\(_\text{max}\)), La, and RPE responses during SSG4 were significantly higher for teams chosen according to AP and CG compared with that of CE and TS (p < 0.05). In addition, teams chosen by AP and CG spent significantly more time in zone 4 (>90% HR\(_\text{max}\)) and covered a greater distance in the high-intensity running zone (>18 km·h) than did teams formed according to TS. Moreover, AP teams covered
significantly greater total distance than TS teams did (p < 0.05). They concluded that to spend more time in both the high-intensity HR zone and the high-intensity running zone, the teams in SSG4 should be formed according to the players' VO₂max values or the values calculated using both the VO₂max and technique scores.

Hill-Haas et al. (2008) examined the variability in physiological and perceptual responses and time-motion profiles of various small-sided soccer game (SSG) formats (2 versus 2, 4 versus 4 and 6 versus 6 players) and regimes (interval and continuous). Typical error (TE) was calculated for mean heart rate as a percentage of maximum heart rate (%HR(max)), global ratings of perceived exertion (RPE), blood lactate [La(-)] and various time-motion characteristics for 16 male soccer players (mean 16.2 years, range 15.6-17.9). The TE for HR responses were <5% for all SSGs. RPE also demonstrated small variability across all SSGs, with TE ranging between 1 and 2 units. In contrast, the TE% for [La(-)] was higher, ranging from 16% (2 versus 2-interval) to 34% (4 versus 4-interval). The TE% for total distance (TD) and distance covered at 0-6.9km/h was <5% for all SSGs, with 2 versus 2 interval and continuous games recording the lowest
TE (2.2% and 2.9%, respectively). An increase in game format size does not appear to influence the variability of the acute physiological responses to SSGs, although continuous formats display less variability than interval formats. The TD, distance covered and percentage of total time moving at 0-6.9km/h demonstrated small variability across all formats and regimes. However, higher movement speed zones (>8km/h) reflected increased variability, irrespective of game format or regime. Collectively, their results suggest that SSG training can provide a reliable aerobic training stimulus.

Atl et al. (2013) compared the heart rate (HR) response and frequency of technical actions between half-court and full-court 3-a-side games in female high school basketball players. Twelve young female basketball players (age 15.5 ± 0.5 years; height 165.1 ± 5.7 cm; body mass 57.3 ± 7.2 kg; training age 4.2 ± 0.7 years; HRmax 202.9 ± 5.6 b·min(-1)) participated in this study voluntarily. On the first day, anthropometric measurements (height and body mass) were taken for each player; this was followed by the Yo-Yo intermittent recovery test (YIRT) level 1 for the subjects. Then, half-court and full-court 3-a-side games were organized in random order at 2-day intervals. The HRmax for each player
was determined during the YIRT, after which the HR was measured during the 3-a-side games. In addition, the frequencies of different categories of technical actions were counted manually during the 3-a-side games. A paired t-test was calculated for each dependent variable, including HR, percentage of maximum HR (%HRmax), and the frequencies of different technical actions to compare half-court and full-court 3-a-side games. The results of the study indicated that the full-court 3-a-side games produced significantly higher responses than the half-court 3-a-side games in terms of HR and %HRmax (p < 0.05), whereas the half-court games resulted in significantly higher frequencies of technical actions (p < 0.05). Their results showed that, if coaches aim is to achieve greater HR responses, coaches of female high school basketball players should organize full-court 3-a-side games, whereas coaches who want to focus on technical actions should arrange half-court 3-a-side games.

Dellal et al. (2011) compared heart rate (HR) responses within and between small-sided games (SSG) training methods in elite young soccer players. Twenty-seven youth soccer players (age: 16.5 ± 0.5 years, height: 174.5 ± 5.5 cm, weight: 62.9 ± 8.3, velocity at maximal aerobic speed (MAS):
15.9 ± 0.9 km.h(-1)) performed 3 different SSG (2 vs. 2, 3 vs. 3, 4 vs. 4 without goalkeeper). In each SSG, HR was continuously measured and expressed as a mean percentage of HR reserve (%HRreserve). The mean %HRreserve calculated during the SSG was significantly lower during 4 vs. 4 (70.6 ± 5.9 %) compared to 2 vs. 2 (80.1 ± 3.6 %, p<0.001) and 3 vs. 3 (81.5 ± 4.3 %, p<0.001) SSG. Regardless of the time spent above 60, 65, 70, 75, 80, 85 and 90 % of HRreserve, 4 vs. 4 solicited lower percentage of time than 3 vs. 3 and 2 vs. 2. Intersubject coefficients of variation were significantly higher during 4 vs. 4 compared to 2 vs. 2 and 3 vs. 3. The %HRreserve after 30s of recovery was significantly higher for 3 vs. 3 (70.6 ± 5.3 %) compared to 2 vs. 2 (65.2 ± 4.8 %, p<0.05) and 4 vs. 4 (61.6 ± 9.3 %, p<0.05). They concluded that their study demonstrated that the physiological demands was higher during 2 vs. 2 and 3 vs. 3 compared to 4 vs. 4 in youth soccer players. The difference could be due to that young soccer players do not have the same technical ability and experience as adult players and thus, their activity during the 2 vs. 2 and 3 vs. 3 induces a greater physical demand due to their lack of experience. The age of the players
could be linked with the physical demands within small-sided games.

**Dellal et al. (2012)** examined the physical and technical activity during different periods within small-sided soccer games (SSGs). 20 elite players completed 3 different SSGs (2-a-side, 3-a-side and 4-a-side games) in which the number of ball touches per individual possession was fixed at a maximum of 2. The duration and the pitch size of each SSG were strictly controlled (2 min, 3 min, 4 min, respectively; 1:75 m2) with each period repeated 4 times (P1, P2, P3, P4). The physical and technical activities, heart rate responses, blood lactate concentration and rating of perceived exertion (RPE) were analysed. Their results showed a decrease of high and very high-intensity activities (from - 26.2% to - 37.7%, P<0.001), an increase of blood lactate concentration (from + 28.0% to + 76.9%), RPE (from + 29.0% to + 32.8%), and heart rate responses (~ 6.6%), and a significant alteration of technical activities from P1 to P4 in each SSG. The greatest differences from P1 and P4 were observed for the 2-a-side game when compared to the 3-a-side and 4-a-side games (P<0.05) for each variable analysed. They concluded that the variation of the player’s activity throughout the periods
indicates that the duration and number of exercise periods used within SSGs is an important variable in determining the training stimulus in soccer-specific training.

Hill-Haas et al. (2011) stated that small-sided games (SSGs) are played on reduced pitch areas, often using modified rules and involving a smaller number of players than traditional football. These games are less structured than traditional fitness training methods but are very popular training drills for players of all ages and levels. At present, there is relatively little information regarding how SSGs can best be used to improve physical capacities and technical or tactical skills in footballers. However, many prescriptive variables controlled by the coach can influence the exercise intensity during SSGs. Coaches usually attempt to change the training stimulus in SSGs through altering the pitch area, player number, coach encouragement, training regimen (continuous vs interval training), rules and the use of goalkeepers. In general, it appears that SSG exercise intensity is increased with the concurrent reduction in player number and increase in relative pitch area per player. However, the inverse relationship between the number of players in each SSG and exercise intensity does not apply to the time-motion
characteristics. Consistent coach encouragement can also increase training intensity, but most rule changes do not appear to strongly affect exercise intensity. The variation of exercise intensity measures are lower in smaller game formats (e.g. three vs three) and have acceptable reproducibility when the same game is repeated between different training sessions or within the same session. The variation in exercise intensity during SSGs can also be improved with consistent coach encouragement but it is still more variable than traditional generic training methods. Other studies have also shown that SSGs containing fewer players can exceed match intensity and elicit similar intensities to both long- and short-duration high-intensity interval running. It also appears that fitness and football-specific performance can be improved equally with SSG and generic training drills. Future research is required to examine the optimal periodization strategies of SSGs training for the long-term development of physiological capacity, technical skill and tactical proficiency.

Bradley and his colleagues (2011) firstly tried to determine the reproducibility of sub-maximal and maximal versions of the Yo-Yo intermittent endurance test level 2 (Yo-Yo IE2 test), secondly to assess the relationship between the
Yo-Yo IE2 test and match performance and lastly tried to quantify the sensitivity of the Yo-Yo IE2 test to detect test-retest changes and discriminate between the performance for different playing standards and positions in elite soccer. Elite (n = 148) and sub-elite male (n = 14) soccer players carried out the Yo-Yo IE2 test on several occasions over consecutive seasons. Test-retest coefficient of variation (CV) in Yo-Yo IE2 test performance and heart rate after 6 min were 3.9% (n = 37) and 1.4% (n = 32), respectively. Elite male senior and youth U19 players Yo-Yo IE2 performances were better (P < 0.01) than elite youth U16s and sub-elite players (2,603 ± 451 and 2,534 ± 549 vs. 1,855 ± 535 vs. 1,749 ± 382 m). The intra and inter-season CV for Yo-Yo IE2 test performance were 4.2 and 5.6%, respectively. A correlation was observed (P < 0.05) between Yo-Yo IE2 test performance and the total (r = 0.74) and high-intensity (r = 0.58) running distance covered in a match. A correlation was also evident (P < 0.01) between Yo-Yo IE2 test heart rate after 6 min expressed in percentage of maximal heart rate and the peak values for high-intensity running performed by midfielders in 5-min (r = -0.71), 15-min (r = -0.75) and 45-min periods (r = -0.77). Their data demonstrate that the Yo-Yo IE2 test is reproducible and can
be used to determine the capacity of elite soccer players to perform intense intermittent exercise. Furthermore, the Yo-Yo IE2 test was shown to be a sensitive tool that not only relates to match performance but can also differentiate between intermittent exercise performance of players in various standards, stages of the season and playing positions.

**Hill-Haas et al. (2009)** compared 7 weeks of soccer-specific small-sided game (SSG) and mixed generic fitness training, on selected physiological, perceptual and performance variables. Twenty-five elite youth players were randomly allocated to either a SSG (coach selected) or generic training group (GTG), in a randomised, parallel matched-group design. In addition to normal training, each group completed two fitness training sessions per week of equal duration. Players completed a VO$_2$ max treadmill test, Multistage Fitness Test (MSFT), Yo-Yo Intermittent Recovery Test Level 1 (YYIRTL1), 12x20 m test of repeated-sprint ability (RSA) and 20-m sprint test pre and post training. Training heart rate, perceived training intensity and perceptual fatigue measures were recorded throughout the training period. There were no differences in training heart rate or perceptual well-being measures. However, the GTG did perceive their
training to be more intense than SSG. There were no changes in either group for VO\textsubscript{2} max, MSFT, RSA or sprint performance. However, there were improvements in YYIRTL1 performance for both groups over time, but not between groups. Their results showed that both types of training are equally effective in improving pre-season YYIRTL1 performance, despite GTG being perceived to be more intense.

*Helgerud et al. (2001)* studied the effects of aerobic training on performance during soccer match and soccer specific tests. Nineteen male elite junior soccer players, age 18.1 +/- 0.8 yr, were randomly assigned to the training group (N = 9) and the control group (N = 10). The specific aerobic training consisted of interval training, four times 4 min at 90-95% of maximal heart rate, with a 3-min jog in between, twice per week for 8 weeks. Players were monitored by video during two matches, one before and one after training. Their results showed that in the training group: a) maximal oxygen uptake (VO\textsubscript{2}max) increased from 58.1 +/- 4.5 ml/kg/min to 64.3 +/- 3.9 ml/kg/min (P < 0.01); b) lactate threshold improved from 47.8 +/- 5.3 ml/kg/min to 55.4 +/- 4.1 ml/kg/min (P < 0.01); c) running economy was also improved by 6.7% (P < 0.05); d) distance covered during a match increased by 20% in the
training group (P < 0.01); e) number of sprints increased by
100% (P < 0.01); f) number of involvements with the ball
increased by 24% (P < 0.05); g) the average work intensity
during a soccer match, measured as percent of maximal heart
rate, was enhanced from 82.7 +/- 3.4% to 85.6 +/- 3.1% (P <
0.05); and h) no changes were found in maximal vertical
jumping height, strength, speed, kicking velocity, kicking
precision, or quality of passes after the training period. The
control group showed no changes in any of the tested
parameters. They concluded that enhanced aerobic
endurance among soccer players improved the soccer
performance by increasing the distance covered, enhancing
work intensity, and increasing the number of sprints and
involvements with the ball during a match.

Hoff et al. (2002) determined whether ball dribbling
and small group play are appropriate activities for interval
training, and whether heart rate in soccer specific training is
a valid measure of actual work intensity. Six well trained first
division soccer players took part in the study. To test whether
soccer specific training was effective interval training, players
ran in a specially designed dribbling track, as well as
participating in small group play (five a side). Laboratory tests
were carried out to establish the relation between heart rate and oxygen uptake while running on a treadmill. Corresponding measurements were made on the soccer field using a portable system for measuring oxygen uptake. Their results showed that exercise intensity during small group play was 91.3% of maximal heart rate or 84.5% of maximal oxygen uptake. Corresponding values using a dribbling track were 93.5% and 91.7%. No higher heart rate was observed during soccer training. They concluded that soccer specific exercise using ball dribbling or small group play may be performed as aerobic interval training. Heart rate monitoring during soccer specific exercise is a valid indicator of actual exercise intensity.

**Gabbett (2008)** investigated the specificity of skill-based conditioning games and compared the effectiveness of skill-based conditioning games and instructional training for improving physical fitness and skill among junior elite volleyball players. Twenty-five junior volleyball players (mean age +/- SE, 15.6 +/- 0.1 years) participated in this study. Heart rate data were collected from all the players during the Australian Junior Volleyball Championships. After the competition, the players were randomly allocated into a skill-
based conditioning games group (n = 12) or an instructional training group (n = 13). Each player participated in a 12-week training program that included 3 organized court training sessions per week. No significant differences (P > 0.05) were detected between competition and skill-based conditioning games for the percentage of time spent in low-intensity, moderate-intensity, and high-intensity activities. Skill-based conditioning games induced improvements in vertical jump, spike jump, speed, agility, upper-body muscular power, and estimated maximal aerobic power, whereas technical instruction improved only spike jump and speed. Conversely, instructional training induced meaningful improvements in all measurements of skill, whereas improvements in technical skill after skill-based conditioning games were uncommon and typically small. Their results showed that skill-based conditioning games offer a specific training stimulus to simulate the physiological demands of competition in junior elite volleyball players. Although the improvements in physical fitness after training were greater with skill-based conditioning games, instructional training resulted in greater improvements in technical skill in these players. Their findings suggested that a combination of instructional
training and skill-based conditioning games is likely to confer the greatest improvements in fitness and skill in junior elite volleyball players.

Kelly and Drust (2009) examined the impact of changes in pitch size on heart rate responses and technical requirements of small-sided soccer games. Eight male soccer players participated in the study (mean±S.D.; age 18±1 years, height 1.80±0.1 m, weight 73.3±6.2 kg, estimated $VO_2^{peak}$ 50.0±3.2 ml/kg/min. All the players participated in small-sided games on three different pitch sizes (SSG1, 30 m x 20 m; SSG2, 40 m x 30 m; SSG3, 50 m x 40 m). Games consisted of 4 x 4 min of game play, interspersed by 2 min of active recovery. Heart rate measurements were made using a team-based monitoring system. Each game was also filmed to evaluate the technical actions. These tapes were analysed using a hand notation system. Mean±S.D. heart rates for the three games were not significantly different between conditions (SSG1, 175±9; SSG2, 173±11; SSG3, 169±6). The technical actions that changed as a result of changes in pitch size were the number of tackles (SSG1, 45±10; SSG2, 15±4; P<0.05) and shots (SSG1, 85±15; SSG 2, 60±18; SSG3, 44±9; P<0.05). Comparisons between the
four 4 min intervals of game play indicated significant differences for both heart rate responses and the technical demands. Their results demonstrate that changes in pitch size do not alter heart rate or the majority of technical requirements observed within small-sided games.

_Coutts et al. (2009)_ examined the relationship between heart rate (%HR peak) and blood lactate measures of exercise intensity with each player's RPE during soccer-specific aerobic exercises. Mean individual %HR(peak), blood lactate and RPE (Borg's CR 10-scale) were recorded from 20 amateur soccer players from 67 soccer-specific small-sided games training sessions over an entire competitive season. The small-sided games were performed in three 4min bouts separated with 3min recovery on various sized pitches and involved 3-, 4-, 5-, or 6-players on each side. A stepwise linear multiple regression was used to determine a predictive equation to estimate global RPE for small-sided games from blood lactate and %HR(peak). Partial correlation coefficients were also calculated to assess the relationship between RPE, blood lactate and %HR(peak). Stepwise multiple regression analysis revealed that 43.1% of the adjusted variance in RPE could be explained by HR alone. The addition of blood lactate
data to the prediction equation allowed for 57.8% of the adjusted variance in RPE to be predicted ($Y=-9.49-0.152 \%HR(\text{peak})+1.82$ blood lactate, $p<0.001$). Their results showed that the combination of blood lactate and $\%HR(\text{peak})$ measures during small-sided games is better related to RPE than either $\%HR(\text{peak})$ or blood lactate measures alone. These results provide further support to the use of RPE as a measure of global exercise intensity in soccer.

Randers et al. (2010) examined the activity profile, heart rate and metabolic response of small-sided football games for untrained males (UM, n=26) and females (UF, n=21) and investigated the influence of the number of players (UM: 1v1, 3v3, 7v7; UF: 2v2, 4v4 and 7v7). Moreover, heart rate response to small-sided games was studied for children aged 9 and 12 years (C9+C12, n=75), as well as homeless (HM, n=15), middle-aged (MM, n=9) and elderly (EM, n=11) men. During 7v7, muscle glycogen decreased more for UM than UF (28 +/- 6 vs 11 +/- 5%; $P<0.05$) and lactate increased more (18.4 +/- 3.6 vs 10.8 +/- 2.1 mmol kg$^{-1}$ d.w.; $P<0.05$). For UM, glycogen decreased in all fiber types and blood lactate, glucose and plasma FFA was elevated ($P<0.05$). The mean heart rate ($HR(\text{mean})$) and time >90% of $HR(\text{max})$ ranged from
147 +/- 4 (EM) to 162 +/- 2 (UM) b.p.m. and 10.8 +/- 1.5 (UF) to 47.8 +/- 5.8% (EM). Time >90% of HR(max) (UM: 16-17%; UF: 8-13%) and time spent with high speed running (4.1-5.1%) was similar for training with 2-14 players, but more high-intensity runs were performed with few players (UM 1v1: 140 +/- 17; UM 7v7: 97 +/- 5; P<0.05): Small-sided games were shown to elucidate high heart rates for all player groups, independently of age, sex, social background and number of players, and a high number of intense actions both for men and women. Thus, small-sided football games appear to have the potential to create physiological adaptations and improve performance with regular training for a variety of study groups.

Castagna et al. (2009) examined the physiological responses and activity pattern to Futsal simulated game-play in professional players. Eight full-time professional outfield Futsal players volunteered for this study: age 22.4 (95% CI 18.8-25.3) years, body mass 75.4 (60-91) kg, height 1.77 (1.59-1.95) m and VO2max 64.8 (53.8-75.8) ml kg(-1) min(-1). Physiological measurements were assessed during highly competitive training games (4x10-min quarters) and consisted of game VO2, game blood-lactate concentration ([lactate]) and
game heart rates (HRs). Game activities were assessed using a computerised video-analysis system. During simulated gameplay players attained 75% (59-92) and 90% (84-96) of VO\(_2\)max and HR(max), respectively. Mean game VO\(_2\) was 48.6 (40.1-57.1) ml kg\(^{-1}\) min\(^{-1}\). Peak game VO\(_2\) and HRs were 99% (88-109) and 98% [90-106] of laboratory maximal values, respectively. Players spent 46 and 52% of the playing time at exercise intensities higher than 80 and 90% of VO\(_2\)max and HR(max), respectively. Mean [la](b) was 5.3 (1.1-10.4) mmol l\(^{-1}\). Players covered 121 (105-137) m min\(^{-1}\) and 5% (1-11) and 12% (3.8-19.5) of playing time spent performing sprinting and high-intensity running, respectively. On an average the players performed a sprint every approximately 79 seconds during play. Their results showed that Futsal played at professional level is a high-intensity exercise heavily taxing the aerobic and anaerobic pathways.

Gabbett and Mulvey (2008) investigated the movement patterns of small-sided training games and compared these movement patterns with domestic, national, and international standard competition in elite women soccer players. In addition, they investigated the repeated-sprint demands of women's soccer with respect to the duration of sprints,
number of sprint repetitions, recovery duration, and recovery intensity. Thirteen elite women soccer players [age (mean +/- SD) 21 +/- 2 years] participated in this study. Time-motion analysis was completed during training (n = 39) consisting of small-sided (i.e., three versus three and five versus five) training games, domestic matches against male youth teams (n = 10), Australian national-league matches (n = 9), and international matches (n = 12). A repeated-sprint bout was defined as a minimum of three sprints, with recovery of less than 21 seconds between sprints. The overall exercise to rest ratios for small-sided training games (1:13) were similar to or greater than domestic competition against male youth teams (1:15) and national-league (1:16) and international (1:12) competitions. During the international matches analyzed, 4.8 +/- 2.8 repeated-sprint bouts occurred per player, per match. The number of sprints within the repeated-sprint bouts was 3.4 +/- 0.8. The sprint duration was 2.1 +/- 0.7 seconds, and the recovery time between sprints was 5.8 +/- 4.0 seconds. Most recovery between sprints was active in nature (92.6%). In contrast to international competition, repeated-sprint bouts were uncommon in small-sided training games, domestic competition against male youth teams, and
national-league competition. Their findings demonstrate that small-sided training games simulate the overall movement patterns of women’s soccer competition but offer an insufficient training stimulus to simulate the high-intensity, repeated-sprint demands of international competition.

Gabbett (2005) provided a comprehensive review of the science of rugby league football at all levels of competition (i.e. junior, amateur, semi-professional, professional), with special reference to all discipline-specific scientific research performed in rugby league (i.e. physiological, psychological, injury epidemiology, strength and conditioning, performance analysis). Rugby league football is played at junior and senior levels in several countries worldwide. A rugby league team consists of 13 players (6 forwards and 7 backs). The game is played over two 30 - 40 min halves (depending on the standard of competition) separated by a 10 min rest interval. Several studies have documented the physiological capacities and injury rates of rugby league players. More recently, studies have investigated the physiological demands of competition. Interestingly, the physiological capacities of players, the incidence of injury and the physiological demands of competition all increase as the playing standard
is increased. Mean blood lactate concentrations of 5.2, 7.2 and 9.1 mmol l(-1) have been reported during competition for amateur, semi-professional and professional rugby league players respectively. Mean heart rates of 152 beats min(-1) (78% of maximal heart rate), 166 beats min(-1) (84% of maximal heart rate) and 172 beats min(-1) (93% of maximal heart rate) have been recorded for amateur, semi-professional and junior elite rugby league players respectively. Skill-based conditioning games have been used to develop the skill and fitness of rugby league players, with mean heart rate and blood lactate responses during these activities almost identical to those obtained during competition. In addition, recent studies have shown that most training injuries are sustained in traditional conditioning activities that involve no skill component (i.e. running without the ball), whereas the incidence of injuries while participating in skill-based conditioning games is low. Collaborative research among the various sport science disciplines is required to identify strategies to reduce the incidence of injury and enhance the performance of rugby league players. An understanding of the movement patterns and physiological demands of different positions at all standards of competition would allow the
development of strength and conditioning programmes to meet the precise requirements of these positions. Finally, studies investigating the impact of improvements in physiological capacities (including the effect of different strength and conditioning programmes) on rugby league playing performance are warranted.

Gamble (2004) evaluated changes in endurance fitness of elite-level rugby union players (n = 35) undertaking skill-based conditioning games for a 9-week preseason training period. Metabolic conditioning was conducted exclusively in the form of skill-based conditioning games in conjunction with heart rate (HR) telemetry. Two markers of cardiorespiratory fitness were assessed at weekly intervals via the recording of HR responses to an intermittent multistage shuttle test. Significant differences post-training were observed for the percentage of maximal HR (% HRmax) reached during the final test stage and the percentage of HR recovery (% HR recovery) from the end of the final stage to the end of the final 1-minute rest period. Significant improvements were demonstrated for % HR recovery at week 7 (p < 0.05) and week 9 (p < 0.01), and % HRmax in the final test stage was significantly lower at weeks 4, 5, and 7 (p <
0.05) and week 9 (p < 0.01). Further improvements from mid-preseason to the end of the preseason training period were observed for % HR recovery scores in week 8 (p < 0.01) and week 9 (p = 0.012) and for % HRmax reached in the final test stage at week 9 (p < 0.05). Their results indicated skill-based conditioning games were successful at improving markers of cardiorespiratory endurance for the duration of a 9-week training period in the elite-level professional rugby union players. The HR monitoring was demonstrated to be an effective and practical means of quantifying intensity in the conditioning games format and of tracking changes in cardiorespiratory fitness.

**Sporis et al. (2008)** evaluated the changes in anaerobic endurance in elite First-league soccer players throughout 2 consecutive seasons, in 2 phases, with and without high-intensity situational drills. Eighteen soccer players were tested before and after the 8-weeks summer conditioning and again in the next season. The measured variables included 300-yard shuttle run test, maximal heart rate, and maximal blood lactate at the end of the test. During the first phase of the study, the traditional sprint training was performed only 2 x weeks and consisted of 15 bouts of straight-line sprinting.
In the second year the 4 x 4 min drills at an intensity of 90-95% of HRmax, separated by periods of 3-minute technical drills at 55-65% of HRmax were introduced. Statistical significance was set at \( P \leq 0.05 \). The traditional conditioning program conducted during the first year of the study did not elicit an improvement in anaerobic endurance as recorded in the 300-yard shuttle run test. After the intervention, the overall test running time improved significantly (55.74 +/- 1.63 s vs. 56.99 +/- 1.64 s; \( P < 0.05 \)) with the maximal blood lactate at the end of the test significantly greater (15.4 +/- 1.23 mmol.L vs. 13.5 +/- 1.12 mmol.L; \( P < 0.01 \)). As a result, their study showed some indication that high-intensity task training was more efficient than straight-line sprinting in improving anaerobic endurance measured by the 300-yard shuttle run test.

**Buchheit et al. (2009)** determined whether a 4-a-side handball (HB) game is an appropriate aerobic stimulus to reach and potentially enhance maximal oxygen uptake (\( \text{VO}_2\text{max} \)), and whether heart rate (HR) is a valid index of \( \text{VO}_2 \) during a handball game. Nine skilled players (21.0 +/- 2.9 yr) underwent a graded maximal aerobic test (GT) where \( \text{VO}_2\text{max} \) and HR-\( \text{VO}_2 \) relationship were determined. \( \text{VO}_2 \), HR and blood
lactate were recorded during a 2 x 225 s (interspersed with 30s rest) 4-a-side handball game and were compared to those measured during an 480-s running intermittent exercise (IE). Mean VO$_2$ tended to be higher in handball compared to IE (93.9+/8.5 vs. 87.6+/7.4% O$_2$max, p=0.06), whereas HR was similar (92.3+/4.9 vs. 93.9+/3.9% of the peak of HR, p=0.10). Blood lactate was lower for handball than for IE (8.9+/3.5 vs. 11.6+/2.1 mmol/l), p=0.04). Time spent over 90% of VO$_2$max was higher for handball than for IE (336.1+/139.6s vs. 216.1+/124.7s; p=0.03). The HR-VO$_2$ relationship during GT was high (r=0.96, p<0.001) but estimated VO$_2$ from HR was lower to that measured (p=0.03) in handball, whereas there was no difference in IE. 4-a-side handball game can be used as a specific alternative to IE for enhancing aerobic fitness in handball players. Nevertheless, the accuracy of HR measures for estimating VO$_2$ during handball is poor.

**Buchheit et al. (2008)** compared the effect of high-intensity interval training (HIT) versus specific game-based handball training (HBT) on handball performance parameters. Thirty-two highly-trained adolescents (15.5+/0.9 y) were assigned to either HIT (n=17) or HBT (n=15) groups, that performed either HIT or HBT twice per week for 10 weeks. The
HIT consisted of 12-24 x 15 s runs at 95% of the speed reached at the end of the 30-15 Intermittent Fitness Test (V(IFT)) interspersed with 15 s passive recovery, while the HBT consisted of small-sided handball games performed over a similar time period. Before and after training, performance was assessed with a counter movement jump (CMJ), 10 m sprint time (10 m), best (RSA best) and mean (RSA mean) times on a repeated sprint ability (RSA) test, the V(IFT) and the intermittent endurance index (iEI). After training, RSA best (-3.5+/-2.7%), RSA mean (-3.9+/-2.2%) and V(IFT) (+6.3+/-5.2%) were improved (P<0.05), but there was no difference between groups. They concluded that both HIT and HBT were found to be effective training modes for adolescent handball players. However, HBT should be considered as the preferred training method due to its higher game-based specificity.

**Summary of literature**

The reviews presented clearly reveals the physical and physiological attributes of handball players. Today, players are exposed more to game based training in particular, game with reduced number of players, field size etc. The reviews clearly show that small sided games are advantages such as
game specific movements, technical training, possible tactical improvements and improve physiological adaptations. This type of training might increase the efficacy of training and even reduce the total training time because of the multi-functionality. This type of games clearly shows the improvement in aerobic fitness, anaerobic endurance and agility in rugby, basketball, volleyball and handball. These small sided games were administered for more than six weeks. The impact of handball specific aerobic training for four and eight weeks is not investigated. The literatures listed above in a sequence clearly highlights the lapses and short coming. Hence the purpose of this study was to assess the effect of handball specific aerobic training on selected physical fitness and physiological variables of male handball players.