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Aerobic Conditioning for Team Sport Athletes

Nicholas M. Stone and *Andrew E. Kilding*

School of Sport and Recreation, AUT University, Auckland, New Zealand

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Abstract

Team sport athletes require a high level of aerobic fitness in order to generate and maintain power output during repeated high-intensity efforts and to recover. Research to date suggests that these components can be increased by regularly performing aerobic conditioning. Traditional aerobic conditioning, with minimal changes of direction and no skill component, has been demonstrated to effectively increase aerobic function within a 4- to 10-week period in team sport players. More importantly, traditional aerobic conditioning methods have been shown to increase team sport performance substantially. Many team sports require the upkeep of both aerobic fitness and sport-specific skills during a lengthy competitive season. Classic team sport trainings have been shown to evoke marginal increases/decreases in aerobic fitness. In recent years, aerobic conditioning methods have been designed to allow adequate intensities to be achieved to induce improvements in aerobic fitness whilst incorporating movement-specific and skill-specific tasks, e.g. small-sided games and dribbling circuits. Such ‘sport-specific’ conditioning methods have been demonstrated to promote increases in aerobic fitness, though careful consideration of player skill levels, current fitness, player numbers, field dimensions, game rules and availability of player encouragement is required. Whilst different conditioning methods appear equivalent in their ability to improve fitness, whether sport-specific conditioning is superior to other methods at improving actual game performance statistics requires further research.

Team sport athletes require a wide range of physical and technical abilities. Specifically, a well developed level of aerobic fitness is desirable in order to recover quickly between repeated high-intensity efforts[1-3] that are typically associated with game-defining moments such as scoring or preventing other teams from scoring. Improving an individual player’s and team’s performance using aerobic conditioning practices has become a priority, and methods to do so have been extensively investigated.[4-18] In order to obtain the necessary articles for this review, several health databases were searched, including EBSCO, PubMed and SPORTDiscus. Key search terms used included ‘aerobic’, ‘basketball’, ‘conditioning’, ‘endurance’, ‘high-intensity’, ‘rugby’, ‘soccer’, ‘sport-specific’, ‘team sports’ and ‘training’. This review specifically focuses on the literature relating to aerobic conditioning interventions and their subsequent influence on aerobic fitness, and, when possible, individual/team sport performance. Based on the articles retrieved, this review differentiates between ‘traditional’, ‘classic’ and ‘modern’ or ‘sport-specific’ aerobic conditioning approaches. Articles were excluded if no measures of aerobic fitness were presented, as this proved difficult to make comparisons with other research. Because of the small number of articles relating to aerobic conditioning interventions and team sport athletes, there was no limit to the search period.

1. Physical Demands of Team Sport Competition

The acyclic, intermittent nature of team sport competition is made evident through the movement frequencies observed during match play being in excess of 1000, regardless of sport.[19-26] The total distance travelled in a match suggests that a well developed level of aerobic fitness is required, especially with respect to outdoor, field-based team sports such as rugby union[21,27] and soccer.[5,23,25,26,28-31] Average game intensity appears to be relatively constant across a range of team sports, equating to just below lactate threshold (LT), i.e. 80–90% peak heart rate (HR_{peak}) or 70–80% peak oxygen uptake ($\dot{V}O_{2peak}$).[5,25,30,32-37] However, when defining characteristics of team sport performances are broken down into low-, medium- and high-intensity activities, clear differences between sports are seen. Players in rugby union[21] and soccer[26,31] appear to spend the greatest amount of time performing low-intensity movements (80–85% of game time), whereas field hockey[38] and basketball[19,20,39] players spend a considerably lower amount of time involved in low-intensity activity (~50% of game time) and more at medium-intensity (~40%). It should be acknowledged that the notable differences both within and between team sports time-motion analysis studies could be due to several reasons: (i) the method used to classify different exercise intensities (i.e. classification of 'zones') is inconsistent between studies; (ii) the number of games analysed could lead to an over- or underestimation of the durations of working at different intensities; (iii) the fitness level of the players analysed could lead to either more or less time engaged in high-intensity activity; and (iv) the importance of the game and the level of the opposition could both increase or decrease the percentage of high-intensity activities performed. Nevertheless, the amount of high-intensity exercise carried out appears consistent across most team sports, accounting for about 15–19% of the total distance covered[26,31,40] or 10–15% of game time.[19,20,41] However, depending on player fatigue levels,[25,32,42] the skill level of the opposition, the importance of the match, or whether the team is winning or losing, the amount of high-intensity exercise performed varies from match to match.[43,44] Heart rate[19,20,23,28,33,35,45-47] and blood lactate concentration[5,8,19-21,23,35,48-51] data reinforce these observations, with moderately high heart rates and lactate concentrations measured during team sport competition. The latter has been significantly correlated to the amount of high-intensity activity performed during the 5 minutes before sampling.[19,52] The energy system contribution to team sport performance tends to reflect game intensity. The majority of the adenosine triphosphate (ATP) required to perform is supplied via aerobic pathways,[19,20,22,28,33,39,41,45,52-55] based on the large amounts of game time spent engaged in low- to moderate-intensity activity.

Based on the physical demands and characteristics of team sport competition, and the potential importance of aerobic fitness, it is clear that a significant portion of the conditioning programmes of team sport players should focus on improving their ability to repeatedly perform high-intensity exercise and to recover. To a large extent both these abilities can be improved by performing aerobic conditioning.

1.1 Physiological Adaptations to Aerobic Conditioning

Several studies have shown that aerobic conditioning is associated with adaptations in the pulmonary,[56-59] cardiovascular,[60-64] neuromuscular[65,66] and metabolic[66-71] systems. However, it is clearly apparent from the literature that the physiological adaptations to training depend upon several factors, including the exercise intensity[72-75] and frequency,[76-79] the duration of training,[69,80] the total length of time of the training programme[76,81,82] and the initial fitness level of the individual.[75,83] These factors interact to determine the overall magnitude of the training response.

Depending on the intensity of aerobic conditioning, physiological adaptation may primarily occur centrally or peripherally.[84] At intensities slightly below LT (~70–80% $\dot{V}O_{2peak}$), physiological adaptations occur primarily in the central component.[81,85] Central adaptations include an improvement in the heart's capacity to pump blood, primarily through increased stroke volume, which occurs because of an increase in end-diastolic volume and an increase in left ventricular mass.[86] Subsequently, these adaptations result in an increased cardiac output, which, according to the Fick equation, will increase $\dot{V}O_{2peak}$.[87] As the training intensity increases above the LT (>80% $\dot{V}O_{2peak}$), significant peripheral adaptation occurs, with substantial changes in muscle capillarization,[88] oxidative enzyme activity,[89] mitochondrial volume and density,[90] and myoglobin,[82] and the preferential use of free fatty acids as an energy substrate.[69] As a consequence of the above central and peripheral adaptations, performance-related aerobic measures such as whole-body $\dot{V}O_{2peak}$,[91] exercise/work economy,[92] LT[93] and oxygen uptake kinetics[94] are all improved.[95]

1.2 Potential Benefits of Aerobic Fitness for Team Sport Performance

The potential benefits of enhanced aerobic fitness for team sport performance are numerous. Although team sport players appear to spend the majority of their time involved in low-to-moderate intensity activities, defensive/offensive success often depends on the less frequent but higher intensity activities that involve combinations of sprinting, jumping and tackling. These high-intensity activities place extreme demands on the anaerobic energy system intermittently throughout the duration of a game. However, overall there is a heavier reliance on the aerobic system, which serves to promote recovery and is engaged during low- to heavy-intensity activities that predominate over 70–90 minutes of whole-body physical activity.

Appropriate aerobic conditioning plays a significant part in allowing players to repeatedly perform high-intensity activity. It has been shown that a high $\dot{V}O_{2peak}$ is moderately related ($r = 0.62$ to $r = 0.68$; $p < 0.05$) to repeat sprint ability (RSA) in field hockey, rugby union and soccer players, as well as endurance-trained and -untrained populations.[1-3] This suggests that the body's ability to deliver and use oxygen, both during and between high-intensity sprints, is important.[96] Furthermore, also in soccer, previous studies have demonstrated that players with a higher aerobic power cover greater distance during a soccer game.[97] Overall, a high $\dot{V}O_{2peak}$ will likely serve to reduce the metabolic disturbances resulting from anaerobic metabolism. Ultimately, players who are aerobically well trained are likely able to maintain their work rates/power output towards the end of a game compared with those with poorer aerobic fitness.

It is possible that short and long RSA could also be influenced by the oxidative potential of the muscle in elite team sport athletes, which may be best reflected by measures of the LT. Indeed, Edwards et al.[98] showed that the LT was a more sensitive indicator to changes in training status in professional soccer players than $\dot{V}O_{2peak}$. Further support for this measure is provided by other studies utilizing fixed blood lactate values. For example, Krustrup et al.[28] demonstrated that the amount of high-intensity running during soccer match play was significantly related to the running speed at 2 mmol/L blood lactate concentration in female players. More recently, Sirotic and Coutts[99] also showed that a significant relationship existed between the running velocity at a blood lactate concentration of 4 mmol/L and prolonged high-intensity intermittent running distance ($r = 0.77$; $p < 0.05$) in 16 moderately trained women team sport athletes. These studies both demonstrate a clear benefit of having well developed aerobic function.

In contrast, however, it should be acknowledged that there are other studies showing that $\dot{V}O_{2peak}$ is a poor indicator of the fitness status of team sport athletes,[98] and it does not relate to performance in either short-term[100] or prolonged intermittent exercise tests among professional players ($r = 0.18$; $p > 0.05$; $n = 8$),[40] nor does it determine the total amount of running distance covered during a game.[28] Also, in well trained subjects, Bishop et al.[100] demonstrated that short-term RSA was not significantly correlated with $\dot{V}O_{2peak}$ in elite team sport athletes ($r = 0.30$; $p > 0.05$). Methodological differences between these conflicting studies such as the standard of player, nature of the games played, different tests used to determine RSA (short and prolonged) and reliability of output measures from time-motion analysis could all account for the inconsistent findings.

In addition to $\dot{V}O_{2peak}$ and LT measures, improvements in $\dot{V}O_2$ kinetics as a result of endurance training have been suggested to increase metabolic efficiency during recovery, which assists in delaying the onset of fatigue.[101] It should be noted that due to recovery time being typically of short duration (<30 sec)[20,22,24,102] during team sport competition, a faster $\dot{V}O_2$ response[103,104] would serve to assist in the replenishment of phosphocreatine stores, which would be re-used across multiple high-intensity efforts. Indeed, athletes with a greater muscle oxidative capacity have been reported to boast greater phosphocreatine resynthesis and an increased ability to remove lactate and hydrogen ions (H^+) from skeletal muscle,[105-108] which will probably be beneficial for team sport athletes.

Given the apparent importance of developing various aerobic fitness measures to enhance various physical output aspects during games in team sports athletes, studies have considered the most effective ways of improving aerobic fitness. Several different approaches can be used to develop the aerobic condition of team sport players. These include a range of traditional, classic and sport-specific (movement-specific) conditioning approaches.

2. Traditional Aerobic Conditioning for Team Sports

2.1 Definition

Traditional aerobic conditioning, defined here as continuous or interval-based straight line running with minimal changes of direction, is used by many athletes and fitness enthusiasts to increase aerobic fitness. Since it has been suggested that $\dot{V}O_{2peak}$ improvements generally occur when a high percentage of $\dot{V}O_{2peak}$ is elicited during exercise,[109] the general goal of interval conditioning is to accumulate a greater training stimulus at high intensities compared with what can be tolerated in a single bout of continuous exercise. This approach is especially important for trained team sport athletes whose increases in aerobic fitness are limited by cardiac output,[110] specifically stroke volume. A recent study by Zhou et al.[111] found that stroke volume increased continuously with increased workload up to $\dot{V}O_{2peak}$ in well trained participants. Consequently, the increased stroke volume up to the level of $\dot{V}O_{2peak}$ in trained athletes has been the rationale behind using high-intensity aerobic conditioning interventions.[5,6,9,112] The prescription of interval training is based on three key variables: work interval intensity and duration, recovery interval intensity and duration, and total work duration (work interval number × work duration). These variables can be manipulated to generate a large range of interval training prescriptions designed primarily to stress aerobic and/or anaerobic energy metabolism. Sufficient physiological data are now available to classify different types of aerobic interval training, ranging in intensity from 85% to 130% of the power or velocity associated with $\dot{V}O_{2peak}$.[113,114]

2.2 Effectiveness of Traditional Aerobic Conditioning

Despite the inclusion of traditional aerobic conditioning in the training programmes of many team sports, surprisingly few studies have documented the true effectiveness of traditional aerobic conditioning approaches in relation to improved physiological measures and their subsequent influence on team sport performance (table I). To date, there is no evidence suggesting that aerobic conditioning does not result in improved team sport performance. While in the few studies that have reported the effects on individual fitness, individual performance and team sport performance, traditional interval conditioning has elicited favourable changes in aerobic fitness and performance, suggesting that traditional aerobic conditioning is an effective approach.[4,5,7]

2.3 Traditional Aerobic Conditioning and Soccer

In a unique training study, Helgerud et al.[5] were among the first researchers to clearly show that high-intensity 'traditional' aerobic interval training significantly influenced a soccer player's aerobic fitness and, perhaps more importantly, their performance during a soccer match. In this study, traditional interval endurance training was performed twice a week, over an 8-week period, at the beginning of the competitive soccer season. Players performed four 4-minute running intervals at 90–95% HR_{peak}, interspersed with 3 minutes of active recovery, jogging at 50–60% HR_{peak}. Consequently, $\dot{V}O_{2peak}$ increased by 10.8% over the duration of the study. LT and running economy improved by 16.0% and 6.7%, respectively ($p < 0.05$), suggesting a marked impact on measures of aerobic function. However, two regular training sessions, involving game play, tactical, technical, strength and sprint training activities, along with one competitive game per week, were performed concurrently with the endurance training. The intensity of these additional training sessions was not reported and, therefore, based on the control groups' post-training increases in $\dot{V}O_{2peak}$ (2%) and number of sprints performed during a match (8%), it is possible that the supplementary training may have contributed towards the improvements in aerobic fitness in the experimental group. Nevertheless, the influence of this improvement on subsequent soccer performance cannot be ignored. The traditional aerobic conditioning resulted in significantly higher exercise

Table I. Traditional aerobic endurance conditioning used in team sports, and the subsequent influence on aerobic fitness and individual/team performance

Study	Sport	No. of subjects	Mean (±SD) age (y)	Season	Training intervention: duration (wk)	sessions per week	mode	intensity	Findings
Balabinis et al.[4]	Basketball	7 males	22.6 ± 0.8		7 SE training	4	100–500 m running intervals every 30–60 sec	85–90% HR_{peak}	Pred $\dot{V}O_{2peak}$ ↑ 13%*
		7 males	22.4 ± 0.5		7 E training	4	100–500 m running intervals every 30–60 sec	85–90% HR_{peak}	Pred $\dot{V}O_{2peak}$ ↑ 7%*
Dupont et al.[7]	Soccer	22 males	20.2 ± 0.7	In	10	1 1	12–15 × 40 m sprints every 30 sec 15 sec work : 15 sec recovery rest × 12–15 sprints	120% MAS	MAS ↑ 8%*** Win percentage ↑ 136%
Helgerud et al.[5]	Soccer	19 males	18.1 ± 0.8	In	8	2	(4 min work : 3 min recovery) × 4, running intervals	90–95% HR_{peak} : 50–60% HR_{peak}	$\dot{V}O_{2peak}$ ↑ 11%* LT ↑ 16%* RE ↓ 7%* No. of sprints ↑ 100%** No. of involvements with ball ↑ 24%* Distance covered ↑ 20%**
Helgerud et al.[6]	Soccer	21 males	25.0 ± 2.9	Pre	8	2	(4 min work : 3 min recovery) × 4, running intervals	90–95% HR_{peak} : 50–60% HR_{peak}	$\dot{V}O_{2peak}$ ↑ 8%*** RE ↓ 4%*

E = endurance; **HR_{peak}** = peak heart rate; **LT** = lactate threshold; **MAS** = maximal aerobic speed; **Pred** = predicted; **RE** = running economy; **SE** = strength and endurance; **$\dot{V}O_{2peak}$** = peak oxygen uptake; ↓ indicates decrease; ↑ indicates increase; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

intensities (3.5%; $p < 0.05$) when expressed in relation to HR_{peak} during a soccer match following the training period. This is presumably related to the improved exercise economy and higher LT as a result of the endurance training. It was also clearly shown that the number of sprints and involvements with the ball increased significantly ($p < 0.05$) from 6.2 to 12.4 (100%) and 47.4 to 58.8 (24%), respectively. Furthermore, a significant increase in the total distance covered (8619 m to 10 335 m, 20%; $p < 0.01$) during a match was observed. Collectively, these results are very encouraging despite the small sample size (n = 19). Furthermore, it must also be acknowledged that quantifying soccer performance based on a single soccer match has its limitations, due to the tactical/technical nature of the game. Playing conditions, skill level of the opposition and importance of the game, amongst other factors, may all have contributed to player performance.[43,44] Analysis of several soccer matches is required to confirm these observations.

More recently, other studies have reported positive physiological adaptation after traditional training approaches. Helgerud et al.[6] performed another study utilizing the same aerobic interval training approach as previously used[5] with a European Champions League team, and found a similar improvement in $\dot{V}O_{2peak}$ (8.1%; $p < 0.001$). This pre-season improvement was observed despite concurrently training for both maximal strength and aerobic endurance. Furthermore, this increase was exhibited in soccer players of a higher standard compared with those used by Helgerud et al.[5] Running economy improved by 3.7% ($p < 0.05$) post-training, perhaps augmented by the maximal strength training that was performed, as resistance training has been demonstrated to benefit exercise economy.[115,116] However, it appears that the concurrent training approach may have slightly hindered the improvement in running economy when compared with a previous aerobic training study involving younger soccer players.[5] Other authors also report significant increases in $\dot{V}O_{2peak}$, LT and running economy, in addition to improvements in individual soccer performance, following traditional aerobic conditioning programmes[5,6] (see also section 5.1).

Using a different approach to the above, Dupont et al.[7] investigated the effect of traditional aerobic conditioning on aerobic fitness in soccer players during the season. A goal of this study was to observe a change in aerobic fitness without any subsequent decrease in match performance. This study demonstrated that one weekly session of short intermittent exercises (12–15 × 15 sec at 120% of maximal aerobic speed) and one weekly session of repeated sprinting exercise (40 m sprints repeated every 30 sec) over 10 weeks induced substantial improvements in aerobic fitness.[7] Maximal aerobic speed improved by 8.1 ± 3.1% ($p < 0.001$). Similar to other studies,[5] the athletes involved in this research also performed two additional team training sessions per week, reportedly involving 'light' exercises. Unfortunately, post-training $\dot{V}O_{2peak}$ was not reported for this study, making comparisons with other research difficult.[5,6] However, given the type of training performed, the improvements in maximal aerobic speed could be a consequence of a greater amount of time spent at $\dot{V}O_{2peak}$.[117] Greater time spent at a high percentage of $\dot{V}O_{2peak}$ during training necessarily induces a positive change in measures of aerobic fitness.[109] With respect to the effects of the conditioning regimen on match performance, the team won 33% of its matches during the 10-week control period (no high-intensity training) and 78% of its matches during the 10-week high-intensity training period. However, this 136% increase must be interpreted with caution, as many factors could have influenced the outcome of games during both the control and the training periods, as described earlier. Overall, the findings of Dupont et al.[7] and Helgerud et al.[5,6] suggest that improvements in $\dot{V}O_{2peak}$ can be achieved during the pre-season and/or early in the season without any decrease in match performance.

2.4 Traditional Aerobic Conditioning and Basketball

Traditional aerobic interval conditioning has also been shown to increase $\dot{V}O_{2peak}$ in collegiate basketball players who simultaneously trained for both muscular strength and aerobic adaptations.[4] Balabinis et al.[4] examined the effects of endurance, strength and concurrent strength and endurance conditioning on several physiological parameters over a 7-week duration (training phase of the season was not stated). Endurance conditioning involved performing between two and ten repeats of 30–1000 m running intervals every 30–60 sec. Endurance conditioning alone improved predicted $\dot{V}O_{2peak}$ by approximately 7%, which was slightly less than that reported by Helgerud et al.[5] Interestingly, however, greater changes in predicted $\dot{V}O_{2peak}$ (13%) were observed when concurrent strength and endurance conditioning was performed (table I), despite all experimental groups being equally matched for aerobic fitness (figure 1) at the start of the study. Given that participants in the studies of both Helgerud et al.[5] and Balabinis et al.[4] displayed similar pre-training $\dot{V}O_{2peak}$ values (58 and 54–55 mL/kg/min, respectively), the greater increase in aerobic function for the strength and endurance-trained group reported by Balabinis et al.[4] may have been augmented by the periodized strength training programme that the group performed. The strength training undertaken was divided into three phases: (i) maximum strength, 1–4 sets × 3–6 repetitions at 75–95% of one repetition maximum (1RM); (ii) explosive power, 4–5 sets × 5–6 repetitions at 70% 1RM; and (iii) muscular endurance, 3 sets × 30–40 repetitions at 40% 1RM. It is very possible that the latter muscular endurance phase promoted

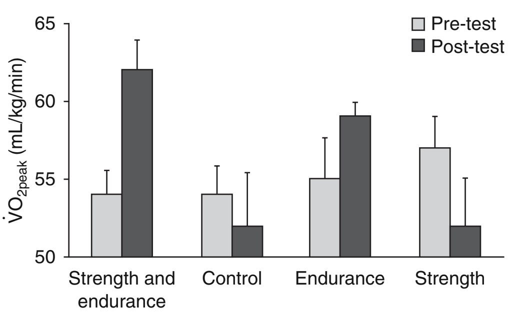

Fig. 1. Mean (±SD) peak oxygen uptake ($\dot{V}O_{2peak}$) for concurrent strength and endurance, control, endurance only and strength only training groups' pre- and post-7-week training intervention.[4]

additional peripheral oxidative adaptations, which has been previously observed in other studies.[118-122] Although Balabinis et al.[4] did not measure aerobic fitness directly, nor any subsequent influence on game performance following the training period, these results suggest that combining strength and endurance training may be a worthwhile approach in basketball for improving aerobic fitness.

2.5 Summary

In summary, it is clear that traditional aerobic conditioning involving repeated running intervals at intensities ranging between 85% and 95% HR_{peak} and lasting up to 4 minutes, separated by a maximum of 3 minutes' active recovery at about 60% HR_{peak}, appears to promote beneficial changes in aerobic function. Such beneficial changes are noticeable when traditional aerobic conditioning is performed twice per week with 24–48 hours of recovery between sessions over periods ranging from 4 to 10 weeks. Some limited evidence exists to suggest that this improvement in fitness is transferable to the actual game situation and subsequently enhances team sport performance. Furthermore, periodized, concurrent strength and endurance training in team sport athletes may elevate $\dot{V}O_{2peak}$ to a greater extent than endurance training alone. The findings of both Dupont et al.[7] and Helgerud et al.[5,6] demonstrate that the aerobic fitness of soccer players can be improved during the competitive season without a decrease in match performance. However, traditional aerobic conditioning methods and their subsequent influence on sport performance is an area requiring further research.

3. Classic Team Sport Conditioning

3.1 Definition

'Classic' team sport conditioning typically integrates strength, power, speed and aerobic conditioning components, directed towards improving the athlete's overall functional and physical capacities specific to their sport, within a coaching framework.[123] Under such conditions, some research, but not all,[124-126] suggests that aerobic power can be maintained and even increased, simply from participation in classic team sport training and competition (table II).[127-131] For example, in basketball, it has been demonstrated that the intensity and duration of running during team practice and competition created sufficient stimulus for the maintenance of aerobic power over single[128,132] and consecutive (four) seasons.[129] However, Hunter et al.[129] reported the training objective for most players was to maintain, not increase, their $\dot{V}O_{2peak}$ (50 mL/kg/min) over the four seasons, based on similar $\dot{V}O_{2peak}$ values reported for other college players.[133] Subsequently, no improvements in $\dot{V}O_{2peak}$ were observed. Conversely, a more recent study involving professional basketball players[134] has shown that a conditioning programme involving speed exercises, technical drills, match situations and endurance training resulted in a marginal increase in $\dot{V}O_{2peak}$ (6%) from pre-season through to the competitive season.

3.2 Effectiveness of Classic Team Sport Conditioning

Observing an increase in $\dot{V}O_{2peak}$ during the competitive season is not unique to basketball. Gabbett[131,135] found that amateur rugby league players undertaking a progressively overloaded training programme involving specific skill, speed, muscular power, agility and endurance training exercises, twice per week, showed an 18–19% increase in predicted $\dot{V}O_{2peak}$ during the course of a rugby league season. The same author in a later study[130] also demonstrated that junior and senior rugby league players increased aerobic fitness by between 5.1% and 8.6% over a 14-week pre-season training period. Despite having lower training loads, junior rugby league players exhibited greater adaptations in predicted relative $\dot{V}O_{2peak}$ than senior rugby league players (8.6% vs 5.1%, respectively). This suggests that junior (~17 years old) and senior (~26 years old) rugby league players adapt differently to an absolute training stimulus and that training programmes should be modified to accommodate differences in training age.[130] Furthermore, across three consecutive pre-season periods, predicted $\dot{V}O_{2peak}$ values in rugby league players have been shown to improve progressively (2001, 7.7%; 2002, 11.8%; 2003, 15.6%; figure 2), with each pre-season period inducing a significant increase ($p > 0.05$) in $\dot{V}O_{2peak}$.[127] This improvement was attributed to a periodized conditioning programme consisting of two game-specific training sessions per week of approximately 60–100 minutes' duration. Interestingly, following the initial season (2001), training loads were decreased through reductions in training duration (2002) and training intensity (2003), but improvements in $\dot{V}O_{2peak}$ were still observed. However, it should be noted that the greater changes in predicted relative $\dot{V}O_{2peak}$ over the three pre-season periods could possibly be a result of the slightly lower pre-training $\dot{V}O_{2peak}$ of players in the 2002 and 2003 pre-season periods.[127] Also, current research has questioned the reliability of the multistage shuttle run test for monitoring changes in $\dot{V}O_{2peak}$.[136] Lamb and Rogers[136] concluded this was due to the large amount of random error associated with various types of predictive equations. In addition, recent research has also failed to show a strong relationship between laboratory-derived $\dot{V}O_{2peak}$ and multistage shuttle run test score,[137] particularly at the elite level.[138] For example, Aziz et al.[137] found only a moderate relationship between $\dot{V}O_{2peak}$ (absolute and relative) and aerobic endurance performance (multistage shuttle run test score) [$r = 0.43$ and $r = 0.54$, respectively] in 37 male soccer players, suggesting that these two tests were measuring different aspects of aerobic fitness. As a result, Kilding et al.[139] have provided modified equations for predicting $\dot{V}O_{2peak}$ from the multistage shuttle run test in team sport athletes. Future research should either use more direct methods for detecting changes in aerobic fitness, or utilize more appropriate predictive methods.

Recently, an off-season classic conditioning approach has been reported to promote increases in $\dot{V}O_{2peak}$ and individual technical skill performance in adolescent basketball players.[140] In this study, players were divided into two training groups: (i) specialized (SP) training, carried out exclusively on the basketball court; and (ii) mixed (MX) training, which was similar to SP training but also included resistance training for muscular strength

Table II. Influence of a 'classic' approach to team sport conditioning on measures of aerobic fitness

Study	Sport	No. of males	Mean (±SD) age (y)	Season	Training				Findings
					duration	sessions per week	session duration (min)	mode	
Bogdanis et al.[140]	Basketball	27[a]	14.7 ± 0.5	Off	4 weeks	5	100–120	Technical, match situations, half and full court 5v5 SSG, and muscular strength and power circuit training	$\dot{V}O_{2peak}$ ↑ 5%* BTS ↑ 17–27%**
Hoffman et al.[128]	Basketball	9	18.8 ± 0.7	Pre, in	25 weeks				1.5 mile run time ↑ 5%
Hunter et al.[129]	Basketball	24			4 competitive seasons	2		1.5–3 mile run	$\dot{V}O_{2peak}$ ↑ ↓
						3		6–20 × 100–440 yard runs	
Laplaud et al.[134]	Basketball	8	24.0 ± 4.0	Pre, in	4.7 ± 0.7 months	19 ± 2 hours		Speed, technical, match situations and endurance training	$\dot{V}O_{2peak}$ ↑ 6% HR_{rest} ↓ 18%**
Tavino et al.[126]	Basketball	9	18–22[b]	Pre, in	6 months	0–5		Weights, aerobic and anaerobic training	$\dot{V}O_{2peak}$ ↓ 5%
Gabbett[130]	Rugby League	36	17.9	Pre	14 weeks	2	60–100	Skill, speed, muscular power, agility and endurance training	Pred $\dot{V}O_{2peak}$ ↑ 9%*
		41	25.5	Pre	14 weeks	2	60–100	Skill, speed, muscular power, agility and endurance training	Pred $\dot{V}O_{2peak}$ ↑ 5%*
Gabbett[135]	Rugby League	36	17.9	Off, pre, in	9 months	2	60–100	Skill, speed, muscular power, agility and endurance training	Pred $\dot{V}O_{2peak}$ ↑ 19%
Gabbett[131]	Rugby League	52	>18	Off, pre, in	9 months	2	60–100	Skill, speed, muscular power, agility and endurance training	Pred $\dot{V}O_{2peak}$ ↑ 18%
Gabbett[127]	Rugby League	79	22.9	2001	10 months	2	60–100	Periodized game-specific training programme	Pred $\dot{V}O_{2peak}$ ↑ 8%*
		65	19.6	2002	10 months	2	60–100	Periodized game-specific training programme	Pred $\dot{V}O_{2peak}$ ↑ 12%*
		76	21.5	2003	10 months	2	60–100	Periodized game-specific training programme	Pred $\dot{V}O_{2peak}$ ↑ 16%*

a Adolescents.

b Range.

BTS = basketball technical skills; **HR_{rest}** = resting heart rate; **Pred** = predicted; **SSG** = small-sided games; **$\dot{V}O_{2peak}$** = peak oxygen uptake; ↓ indicates decrease; ↑ indicates increase; ↑ ↓ indicates no change; * $p < 0.05$, ** $p < 0.01$.

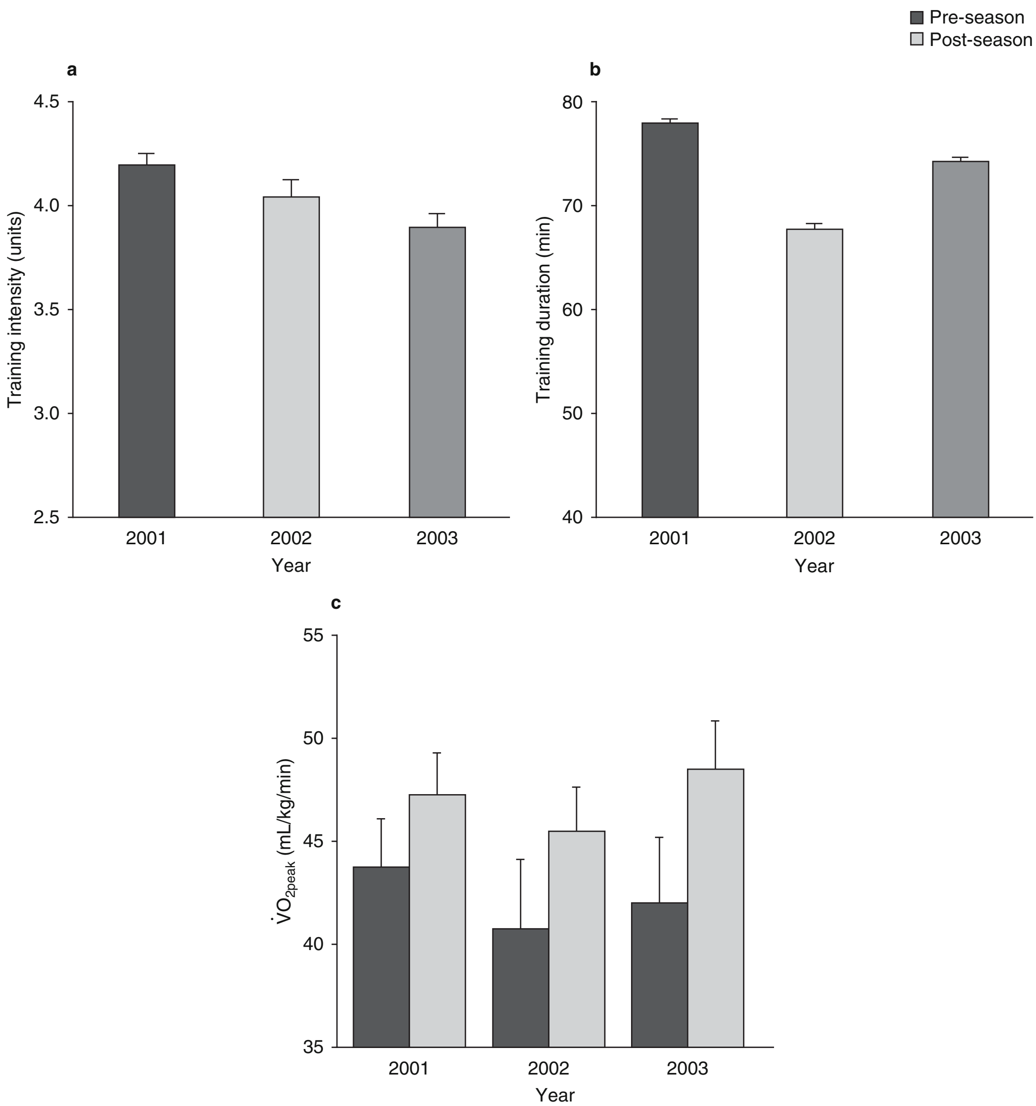

Fig. 2. (**a**) Overall training intensity, (**b**) duration, and (**c**) peak oxygen uptake ($\dot{V}O_{2peak}$) of sub-elite rugby league players over three consecutive pre-season preparation periods. Values are mean ± 95% CI (reproduced from Gabbett,[127] with permission from BMJ Publishing Group Ltd).

and power (see Bogdanis et al.[140] for more details on training design). Both training programmes included five training sessions per week, each lasting 100–120 minutes, for 4 weeks. No training intensity was prescribed; however, intensity was evaluated by continually monitoring heart rate during the training sessions. Training load in both the SP and MX training groups was similar (low intensity: 58.4 ± 3.0 vs 64.2 ± 2.7%; moderate intensity: 37.0 ± 2.4 vs 32.6 ± 1.0%; high intensity: 4.6 ± 1.2 vs 3.2 ± 1.0% for the SP and MX groups, respectively). A relatively small but substantial improvement in aerobic fitness was observed following both SP and MX training programmes (SP: 4.9 ± 1.8%; MX: 4.9 ± 1.4%; $p < 0.05$), despite the training not being specifically designed to improve $\dot{V}O_{2peak}$.[140] The small increase could be due to the aerobic stimuli of classic basketball training typically not being adequate to induce more substantial improvements in aerobic fitness,[140] and that insufficient time (5–7%) was spent at training intensities associated with greater increases in $\dot{V}O_{2peak}$.[109] Additionally, aerobic fitness typically declines in team sport athletes during the off-season, which is evident from lower pre-season yo-yo intermittent recovery test (IRT) scores than end-season scores in soccer players.[125] Therefore, a lower $\dot{V}O_{2peak}$ could have potentially contributed to the increase in aerobic fitness. These results help reinforce the findings of Balabinis et al.[4] in that additional traditional aerobic training in conjunction with resistance training may lead to greater gains in aerobic fitness. Perhaps more relevant to team sport performance, Bogdanis et al.[140] showed an improvement (15–25%; $p<0.01$) in four basketball-specific technical skills (speed shot shooting, passing, dribbling and defensive sliding) following the training period for both groups. An improvement in individual technical skill would logically transfer into better individual/team performance during a basketball game, which warrants further research during the competitive season.

3.3 Limitations of a Classic Approach

Despite these positive changes in fitness, especially $\dot{V}O_{2peak}$, findings from a number of studies refute the notion that classic team sport training can result in substantial changes in aerobic fitness. For example, seasonal changes in aerobic fitness of elite soccer players appear to increase through to the start of the competitive season (25%) and decline, by 5%, when measured at the end of the season, as illustrated in figure 3.[125] A similar trend has been observed in a recent analysis of the aerobic fitness of soccer players over the course of a soccer season.[141] Similarly, college basketball training and competition has been reported to have little effect on aerobic capacity during a season.[124,126] A pre-season training programme consisting of anaerobic conditioning (5 × per week), weight training (3 × per week), scrimmages (2–4 × per week) and aerobic conditioning (5 × per week)[126] resulted in a 4.7% increase in $\dot{V}O_{2peak}$. However, during the competitive season, only scrimmages (intra-team games) and anaerobic conditioning were continued, in conjunction with approximately two basketball games per week. Consequently, a 5.3% decrease in aerobic fitness over the course of the competitive season was observed. When the conditioning focus of the training programme does not include aerobic conditioning, minimal changes in $\dot{V}O_{2peak}$ would be expected, which could be detrimental to individual and team performance. However, it could be argued that the exclusion of aerobic conditioning from in-season professional basketball practice is warranted, given that Gillam[124] observed a negative relationship between points scored per minute of play and the cardiovascular endurance of players ($r=-0.66$). This is supported indirectly by the more recent findings of Hoffman et al.,[123] who reported a low correlation ($r=0.10$) between the total amount of playing time per player and aerobic endurance in basketball athletes, suggesting that those with the highest levels of aerobic fitness had the least amount of playing time. The major determinant of playing time in this study was the coach's evaluation of the player's ability.

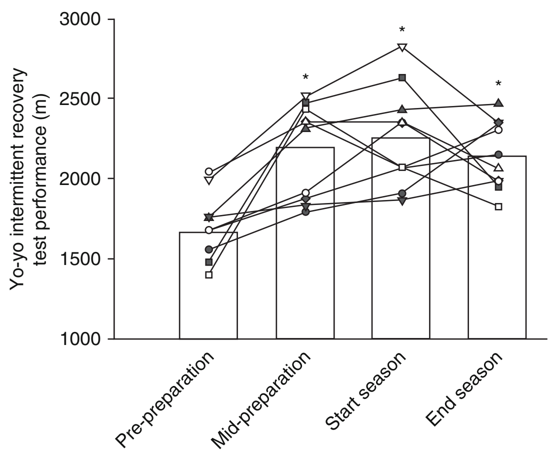

Fig. 3. Seasonal changes in yo-yo intermittent recovery test performance for elite soccer players. Values are mean ± SEM as well as individual values. * Denotes significant difference ($p<0.05$) from pre-preparation period (reproduced from Krustrup et al.,[125] with permission from Lippincott Williams and Wilkins).

3.4 Summary

Overall, the aerobic capacity of team sport players (basketball, rugby league and soccer) has been shown to increase throughout the preseason and decrease during the competitive season, when using a classic team sport conditioning approach.[125,126] The reduced attention to aerobic conditioning during the competitive season, in some sports, suggests that the importance of aerobic endurance may be underrated. In some instances this may be warranted, if other aspects (technical or physical) are shown to be more important. Accordingly, it appears that coaches, along with strength and conditioning professionals, prioritize training regimens focused on improving anaerobic fitness during the competitive season, most probably because high-intensity activities are associated with important game winning situations, such as scoring points in basketball or a try in rugby union. However, it should be emphasized that a lack of focus on aerobic conditioning is also very likely to influence the ability to repeatedly perform, and recover from, high-intensity activity (sprints), so the absence of aerobic conditioning during the competitive season, regardless of sport, may not represent best practice in terms of optimizing the condition of athletes. Further research is needed to determine the impact of classic team sport conditioning regimens on aerobic fitness and possibly game performance so that the strengths and weaknesses of such approaches can be identified for different team sports. Future training studies can then be developed to further develop strengths and improve on weaknesses. Furthermore, there is a need for strategies to be developed that show coaches of team sports how two components of the game can be worked on simultaneously, such as aerobic endurance and technical skill.

4. Sport-Specific Aerobic Conditioning for Team Sports

4.1 Definition

The departure from traditional aerobic conditioning methods appears to be the result of the design and greater use of sport-specific aerobic conditioning sessions. Sport-specific aerobic conditioning generally involves small-sided conditioning games or dribbling tracks/circuits, which incorporate skills and movements specific to the sport into a physical framework. Indeed, such aerobic conditioning methods are being increasingly implemented in professional team sport environments (table III)[142,143] with an increased emphasis on training ‘with the ball’ where possible.[8-14,130] The perceived benefits of performing sport-specific exercise, rather than traditional aerobic conditioning, are that: (i) the training will transfer better into the athletes’ competitive environment; (ii) the greatest training adaptations will occur when the training stimulus simulates the specific movement patterns and physiological demands of the sport;[83] (iii) skill-based conditioning games provide an opportunity to develop decision-making and problem-solving skills, under stressful physical loads;[144] and (iv) it is possible that team sport players may respond better psychologically, in terms of motivation, to sport-specific physical conditioning rather than nonspecific traditional, continuous or interval-based conditioning. In consideration of these factors, researchers have designed and investigated the efficacy of various sport-specific methods to develop aerobic endurance.[9,18]

4.2 Examples of Sport-Specific Aerobic Conditioning

Sport-specific aerobic conditioning can take many forms. One example is a dribbling circuit that incorporates changes of direction, acceleration and deceleration and skills specific to the sport. Such circuits have been utilized to improve aerobic fitness, especially in soccer.[8,9,13] One of the first studies to investigate the effectiveness of this strategy was conducted by Hoff et al.,[9] who designed a soccer-specific dribbling track (figure 4), where accelerations, changes of direction and activities with the ball were used for specific interval training, alongside small-sided games. In Norwegian first division players, Hoff et al.[9] reported that interval training using

Table III. Soccer-specific aerobic conditioning in team sports and the subsequent influence on aerobic fitness

Study	No. of subjects	Mean (± SD) age (y)	Season	Training intervention				Findings
				duration	sessions per week	mode (work : recovery)	intensity	
Chamari et al.[8]	18 M	14.0 ± 0.4	In	8 weeks	2	(4 min : 3 min) × 4, Hoff Track and 4v4 SSG	90–95% HR_{peak} : 60–70% HR_{peak}	$\dot{V}O_{2peak}$ ↑ 8% RE ↓ 14%**
Hoff et al.[9]	6 M	22.2 ± 3.3				(4 min : 3 min) × 4, Hoff Track (4 min : 3 min) × 4, 5v5 SSG	90–95% HR_{peak} : 70% HR_{peak} 90–95% HR_{peak} : 70% HR_{peak}	94% HR_{peak}, 92% $\dot{V}O_{2peak}$[a] 91% HR_{peak}, 85% $\dot{V}O_{2peak}$[a]
Kelly and Drust[10]	8 M	18.0 ± 1.0				(4 min : 2 min) × 4, 5v5 SSG, 30 × 20 m pitch (4 min : 2 min) × 4, 5v5 SSG, 40 × 30 m pitch (4 min : 2 min) × 4, 5v5 SSG, 50 × 40 m pitch		91% HR_{peak}[a] 90% HR_{peak}[a] 89% HR_{peak}[a]
Little and Williams[11]	23 (sex not given)	22.8 ± 4.5				(2 min : 2 min) × 4, 2v2 SSG, 30 × 20 m pitch (3 min : 1.5 min) × 4, 3v3 SSG, 40 × 30 m pitch (3.5 min : 2 min) × 5, 4v4 SSG, 50 × 30 m pitch (5 min : 1.5 min) × 3, 5v5 SSG, 55 × 30 m pitch (6 min : 1.5 min) × 3, 6v6 SSG, 60 × 40 m pitch (10 min : 1.5 min) × 3, 8v8 SSG, 70 × 45 m pitch (2 min : 2 min) × 5, 5v5 pr SSG, 60 × 35 m pitch (2 min : 2 min) × 5, 6v6 pr SSG, 65 × 30 m pitch		91% HR_{peak}[a] 91% HR_{peak}[a] 90% HR_{peak}[a] 89% HR_{peak}[a] 88% HR_{peak}[a] 88% HR_{peak}[a] 90% HR_{peak}[a] 91% HR_{peak}[a]
Little and Williams[12]	28 (sex not given)	24.0 ± 5.0	In			(2 min : 2 min) × 4, 2v2 SSG, 30 × 20 m pitch (3.5 min : 1.5 min) × 4, 3v3 SSG, 43 × 25 m pitch (4 min : 2 min) × 4, 4v4 SSG, 40 × 30 m pitch (6 min : 1.5 min) × 4, 5v5 SSG, 45 × 30 m pitch (8 min : 1.5 min) × 3, 6v6 SSG, 50 × 30 m pitch		89% HR_{peak}[a] 91% HR_{peak}[a] 90% HR_{peak}[a] 89% HR_{peak}[a] 88% HR_{peak}[a] 88% HR_{peak}[a]

Continued next page

Table III. Contd

Study	No. of subjects	Mean (± SD) age (y)	Season	Training intervention				Findings
				duration	sessions per week	mode (work : recovery)	intensity	
						(8 min : 1.5 min) × 4, 8v8 SSG, 70 × 45 m pitch		
McMillan et al.[13]	11 M	16.9 ± 0.4	Pre, in	10 weeks	2	(4 min : 3 min) × 4, Hoff Track	90–95% HR_{peak} : 70% HR_{peak}	$\dot{V}O_{2peak}$ ↑ 11%*** HR @ 9 km/h ↓ 5%*
Rampinini et al.[14]	20 M	24.5 ± 4.1	Pre, in	8 months	2	(4 min : 3 min) × 3, 3v3 up to 6v6 SSG on varying pitch dimensions	>83% HR_{peak} : unknown	Yo-yo IRT ↑ 7%** Yo-yo ET ↑ 44%***

a Findings demonstrate the intensities achieved during one bout of the training mode.

ET = endurance test; **HR** = heart rate; $\mathbf{HR_{peak}}$ = heart rate peak; **IRT** = intermittent recovery test; **M** = male; **pr** = pressure half switch; **RE** = running economy; **SSG** = small-sided games; $\mathbf{\dot{V}O_{2peak}}$ = peak oxygen uptake; ↓ indicates decrease; ↑ indicates increase; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

a dribbling track resulted in physical loads equivalent to 94% HR_{peak} and 92% $\dot{V}O_{2peak}$, which are optimal intensities for developing aerobic fitness.[109] Similarly, it was demonstrated that accompanying interval training sessions using small-sided games (5 vs 5) induced steady-state exercise intensities of 91% HR_{peak}, corresponding to approximately 85% $\dot{V}O_{2peak}$. The small sample size in this study (n = 6) is an obvious limitation; however, other recent research reinforces this finding where exercise intensities achieved during small-sided games of various conditions were found to range from 87% to 91% HR_{peak}.[10-12] Together, both training modes provided an optimal training intensity. Interestingly, however, players with the highest $\dot{V}O_{2peak}$ elicited the lowest percentage of $\dot{V}O_{2peak}$ during small-sided games, suggesting that the playing situation designed for this experiment had a ceiling effect for the achievable intensity, and consequently the development of aerobic endurance. That is, the technical/tactical constraints of the game prevented maximal intensities from being reached for some players. Therefore, for athletes with an already high aerobic capacity, and with a good skill level, the aerobic energy system would not be fully stimulated under these training conditions.

It may be preferential to prescribe traditional, interval-based, aerobic conditioning, where high workloads can be achieved for sustained periods. Alternatively, it is possible that with some modification – e.g. reducing the number of players, coach encouragement, or increasing the pitch size – such small-sided games may elicit a more intense/strenuous scenario, which could be physiologically beneficial for athletes with a relatively high initial aerobic fitness. In support, it has been shown that three-a-side small-sided games result in more high-intensity activity, greater overall distance covered, less jogging, less walking, higher heart rates and more tackling, dribbling, goal attempts and passes than five-a-side soccer games.[145] Likewise, some evidence suggests that when player numbers are kept constant, a larger playing area increases the intensity of the activity, while a smaller playing area has the opposite effect.[14] Independent of player numbers and

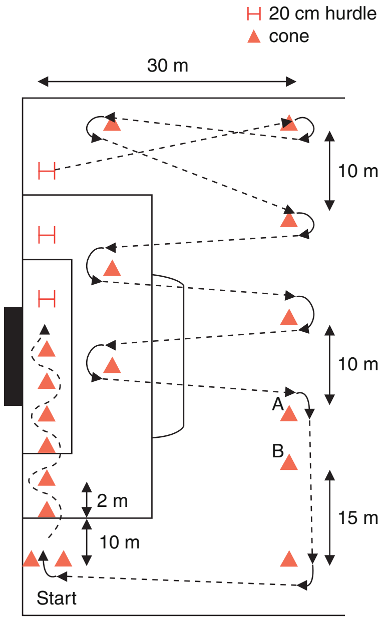

Fig. 4. Soccer-specific dribbling track – 'The Hoff Track' (reproduced from Hoff et al.,[9] with permission from BMJ Publishing Group Ltd).

pitch size, the skill level of the player may influence the achievable exercise intensity. For example, it has been reported that junior players, with less skill, are not able to maintain the skill/drill/technique at a fast enough pace, or with sufficient consistency, to achieve and maintain the required metabolic stress; as such, training may be counterproductive.[146] Such athletes may not achieve the optimal physiological adaptation during sport-specific aerobic conditioning, which might negatively influence future playing performance. Clearly, examining the characteristics of responders versus non-responders (e.g. age, skill level and fitness level) to modern aerobic conditioning approaches, such as small-sided games and dribbling circuits, presents itself as a future research opportunity.

4.3 Small-Sided Games for Soccer

As mentioned above, the modifiable characteristics/parameters of small-sided games may be influential in determining physical loads. In a comprehensive study, Rampinini et al.[14] examined the effects of player numbers, field dimensions and coach encouragement on the exercise intensity of small-sided soccer games, designed specifically for aerobic conditioning. Twice per week, over 8 months, 20 amateur soccer players performed a total of 67 three-, four-, five- or six-a-side games as interval training. Games were played on three different-sized pitches with varying dimensions (small: 12–24 × 20–32 m; medium: 15–30 × 25–40 m; large: 18–36 × 30–48 m), with and without coach encouragement. Each small-sided game consisted of three bouts of 4 minutes, with 3 minutes of active recovery separating bouts. A specific training intensity was not prescribed for the work intervals, nor was the type of activity defined for the recovery periods. Although not the primary aim of the study, performance measures following the training period increased, with the group mean for the yo-yo IRT improving by 7.4% ($p < 0.01$) and for the yo-yo endurance test, by an extraordinary 44.3% ($p < 0.001$). These increases provide evidence of the benefits of performing sport-specific aerobic conditioning in soccer players. An improvement in yo-yo IRT performance suggests a potential increase in soccer performance, given that the amount of high-intensity running performed during a soccer match has been closely associated with the distance covered during the yo-yo IRT.[125] The factor that had the greatest impact on the physiological response to small-sided games was encouragement, followed by player numbers and field dimensions.[14] Three-a-side games were more intense than four-, five- and six-a-side games, irrespective of field dimensions and coach encouragement. Higher exercise intensities when fewer players are on the pitch might be due to the players having more possession of the ball.[147,148] In the same way, a larger pitch size produced higher exercise intensities than a smaller size (1%; $p < 0.017$), independent of player numbers and coach encouragement, albeit only marginally. Not surprisingly, in all situations, small-sided games with coach encouragement produced higher heart rate (2.5%) and blood lactate concentration (30%) responses than without. By manipulating such variables, it would be possible to impose a sufficient physiological stress on players already possessing a high level of aerobic fitness. A factor not considered by Rampinini et al.[14] was the impact of playing rules, or 'conditions', on the physiological responses to small-sided games.

In contrast to Rampinini et al.,[14] Kelly and Drust[10] showed that when player numbers are kept constant, pitch dimensions do not seem to influence the intensity of small-sided games when expressed as $\%HR_{peak}$ (table III). In addition, no significant difference was observed in the total number of technical actions (passing, receiving, turning, dribbling, interceptions and heading) performed by players when pitch dimensions increased. The similarity in the frequency of technical actions across varying pitch dimensions suggests that pitch size is not a major determinant of the number of technical actions performed.[10] However, important technical actions, such as shots on goal, were significantly greater using a small pitch than with a medium or large pitch (small: 85 ± 15; medium: 60 ± 18; large: 44 ± 9; $p < 0.05$). Therefore, these findings suggest that altering pitch dimensions should be considered if a combined physical training stimulus and technical work on shooting in soccer is desired. The differing results of Rampinini et al.[14] and Kelly and Drust[10] demonstrate the need for a better understanding of the factors that contribute to overload in small-sided games.

Other research into small-sided soccer games has revealed such modes of aerobic conditioning are a reliable aerobic training stimulus.[11,149] The work of Hill-Haas et al.[149] and Little and Williams[11] has demonstrated low variability across a variety of small-sided game formats where player numbers and pitch dimensions have been altered. Such studies have demonstrated low variability in physiological measures (such as $\%HR_{peak}$[11,149]) and time-motion measures (such as total distance covered and percentage of total time at low velocities[149]) during both continuous and interval-based small-sided games. However, test-retest variability tends to increase for higher velocities,[149] possibly due to global positioning systems only sampling distance at 1 Hz combined with the duration of high-intensity efforts being very brief (<2 sec). The reliability of the physiological responses and external loads observed during small-sided conditioning games for soccer suggest that such training modes allow for optimized group physical conditioning and therefore represent a viable alternative to traditional running interval training for developing and maintaining aerobic fitness.

Similar to the work of Hoff et al.,[9] Chamari et al.[8] reported on an 8-week (twice per week) training study involving 18 young male soccer players. Once per week, players performed four 4-minute bouts on the Hoff track, at 90–95% HR_{peak}, separated by 3 minutes' active recovery at 60–70% HR_{peak}. During the second session, on the following day, players participated in small-sided games (4 vs 4) on a 20 m square pitch, at the same intensity as in session one. The 3-minute active recovery involved two players passing and juggling with the ball. When expressed in mL/kg/min, this training regimen resulted in a 7.5% increase in $\dot{V}O_{2peak}$ and a 14% improvement in running economy when running at 7 km/h. Heart rate at 7 km/h also decreased by 9 beats/min, indicating improved stroke volume. Likewise, with 16 young male soccer players, McMillan et al.[13] demonstrated that 10 weeks of aerobic endurance training, using the Hoff track in a similar manner to Chamari et al.,[8] was equally effective in elevating $\dot{V}O_{2peak}$ (6.4 mL/kg/min, or 9%). Given these reported improvements in $\dot{V}O_{2peak}$, and considering the findings of previous research,[5] it is reasonable to suggest that a concomitant increase in total distance travelled and average exercise intensity would be observed during a competitive match, following each training period. Unfortunately, weaknesses in both the Chamari et al.[8] and McMillan et al.[13] studies were a low sample size, the lack of a control group, and that no match performance measures were reported following the training intervention periods. Despite these limitations, both studies demonstrate that a specifically designed dribbling track, and small-sided conditioning games, allow young soccer players to perform at high percentages (>85%) of HR_{peak} and $\dot{V}O_{2peak}$, resulting in improvements in $\dot{V}O_{2peak}$ of 7.5–9% over an 8- to 10-week period.

Regardless of the recent advances in aerobic conditioning for team sport athletes, elite soccer players who are playing the most matches and are training the most for soccer still have only modest $\dot{V}O_{2peak}$ values – typically an average of 60–64 mL/kg/min.[6] Hoff and Helgerud[112] have addressed this, explaining that the stroke volume of the heart needs to be increased by achieving high cardiac outputs for sustained periods during training. This consequently leads towards a training model that is of high aerobic intensity, but also with a duration long enough to create high cardiac output without breaking the muscular-venous pumping action that is fundamental for a high stroke volume.[86] This potentially indicates, from a purely physiological perspective, that small-sided games could have a potential limitation in providing a sufficient stimulus, as they are often more intermittent than traditional methods of training (i.e. interval running), thus setting the muscular-venous pump to zero and consequently not allowing a high stroke volume to be achieved. In consideration of this, the rules/structure of small-sided games could be manipulated to create fewer stops in player movement in an attempt to create a greater cardiovascular load.

4.4 Small-Sided Games for Other Sports

Most previous sport-specific training studies have considered soccer; however, there are also studies in other sports, such as rugby league[18,150] and rugby union.[151] Skill-based conditioning games for rugby league have been designed to develop specific aspects of the game, including scrambling defence and support play, the ability to play the ball at speed, defence line speed, ball control and patience. During such conditioning activities, Gabbett[150] measured similar heart rate (152 vs 155 beats/min) and blood lactate concentrations (5.2 vs 5.2 mmol/L) during competition and training, which suggests that skill-based conditioning games have the capacity to replicate the intensity of rugby league competition. However, simply replicating game intensity is not enough to induce reasonable improvements in aerobic function, which, as outlined previously, depends on factors such as exercise intensity and duration.[109] A more detailed discussion of the effectiveness of skill-based conditioning games, when compared with traditional aerobic conditioning methods for rugby league players, can be found below (section 5). In addition, blood lactate measures have been reported to be a poor indicator of muscle lactate[51] and are directly influenced by the amount of high-intensity activity performed within 5 minutes of the blood sample being taken.[19] Therefore, such observations must be interpreted with caution. Likewise, the primary activities of skill-based conditioning games in rugby league and rugby union tend to be focused largely on technique compared with physical development (although this will happen to some extent at the same time), and this may influence the extent of improvements in specific aerobic parameters such as $\dot{V}O_{2peak}$ and exercise economy.

4.5 Summary

There is no doubt that sport-specific aerobic conditioning has the ability to induce positive changes in aerobic fitness (and technique under physical load), as demonstrated by the collective results of the described studies. However, athletes with high fitness levels and young players with limited skill may not benefit from small-sided games if the specifics of the game (number of players involved and pitch size) are not considered. Dribbling circuits may be more beneficial in this respect. Regardless, in most studies, evidence of the impact of sport-specific aerobic conditioning on subsequent game performance is lacking, though the inherent difficulties and challenges in collecting worthwhile match performance data are acknowledged.

5. Traditional versus Sport-Specific Aerobic Conditioning for Team Sports

Whilst there has been an increase in the use of sport-specific conditioning approaches for team sports, several researchers have questioned the effectiveness when compared with traditional methods of conditioning (table IV).[16-18,152] Since a number of investigations,[125,126,141] but not all, have shown that aerobic fitness declines

Table IV. Effect of traditional vs sport-specific aerobic conditioning on team sport performance and aerobic fitness

Study	Sport	No. of subjects	Mean (±SD) age (y)	Season	Group	Training intervention duration (wk)	sessions per week	session duration (min)	mode (work : recovery)	intensity	Findings
Gabbett[18]	Rugby League	37 M	22.1 ± 0.9	In	Spec	9	2	60–100	Skill-based conditioning games		Pred $\dot{V}O_{2peak}$ ↑ 5%* 3 : 1 win-loss ratio
		32 M	22.3 ± 0.8	In	Trad	9	2	60–100	Speed, power, agility and endurance training		Pred $\dot{V}O_{2peak}$ ↑ 5%* 3 : 1 win-loss ratio
Impellizzeri et al.[15]	Soccer	14		Pre and In	Spec	12	2		(4 min : 3 min) × 4, SSG	Unknown : 60–70% HR_{peak}	Distance covered ↑ 4% HI activity ↑ 26%
		15		Pre and In	Trad	12	2		(4 min : 3 min) × 4, running intervals	90–95% HR_{peak} : 60–70% HR_{peak}	$\dot{V}O_{2peak}$ ↑ 8% %$\dot{V}O_{2peak}$ at LT ↑ 4% RE at LT ↓ 3% Distance covered ↑ 6% HI activity ↑ 23%
Reilly and White[16]	Soccer	9	18.2 ± 1.4		Spec	6	2		(4 min : 3 min) × 6, 5v5 SSG	Unknown: 50–60% HR_{peak}	$\dot{V}O_{2peak}$ ↑↓ La_{peak} ↑↓
		9	18.2 ± 1.4		Trad	6	2		(4 min : 3 min) × 6, running intervals	85–90% HR_{peak} : 50–60% HR_{peak}	La_{peak} ↑↓
Sassi et al.[17]	Soccer	9			Spec				4v4 and 8v8 SSG		91% $HR^{\dagger}_{peak}$
					Trad				Running intervals		85% $HR^{\dagger}_{peak}$

a Findings demonstrate the intensities achieved during one bout of the training mode.

HI = high-intensity; **HR_{peak}** = heart rate peak; **La_{peak}** = lactate peak; **LT** = lactate threshold; **M** = male; **Pred** = predicted; **RE** = running economy; **SSG** = small-sided games; **Spec** = sport-specific training group; **Trad** = traditional training group; **$\dot{V}O_{2peak}$** = peak oxygen uptake; ↓ indicates decrease; ↑ indicates increase; ↑↓ indicates no change; * $p < 0.05$.

throughout the competitive season, a priority for team sport athletes during the competitive season must be to focus on at least maintaining aerobic fitness, while at the same time keeping up the practice of game skills.[16] Sport-specific aerobic conditioning methods may prove useful in achieving such priorities, especially when the time between competitive engagements is short. However, coaches and trainers alike need reassurance that sport-specific methods are as effective as traditional approaches for developing aerobic fitness. It has yet to be clearly identified whether a combined training stimulus of skill-based conditioning games, traditional conditioning activities and strength training would improve physiological capacities to a greater extent than either skill-based conditioning games or traditional conditioning activities alone. Nevertheless, many authors have proposed sport-specific exercises, such as small-sided games, as an alternative mode of aerobic conditioning for team sport athletes.[11,12,16-18,149,152]

5.1 Traditional and Sport-Specific Aerobic Conditioning Approaches in Soccer

Several studies have compared the effectiveness of traditional aerobic interval conditioning with skill-based conditioning games in soccer players.[16,17,152] Reilly and White[16] trained 18 professional, premier league soccer players twice per week for 6 weeks. Sport-specific conditioning involved six 4-minute bouts of 5 versus 5 small-sided games, interspersed with 3 minutes of active recovery (jogging at 50–60% HR_{peak}). Intensity of work intervals during the small-sided games was not reported. Aerobic interval conditioning involved performing six 4-minute periods of running at 85–90% HR_{peak}, interspersed with 3 minutes' active recovery, again jogging at 50–60% HR_{peak}. After the training intervention, predicted $\dot{V}O_{2peak}$ increased by 0.2% (57.7 ± 3.0 to 57.8 ± 3.0 mL/kg/min) for the sport-specific group and by 0.3% (57.8 ± 3.2 to 58.0 ± 3.2 mL/kg/min) for the aerobic interval group. This negligible improvement in $\dot{V}O_{2peak}$ is somewhat surprising, given that the prescribed intensity of interval work was similar to that previously employed,[5,8,13] where, despite higher pre-training $\dot{V}O_{2peak}$ values than reported here, the training intervention resulted in large (7.5–9%) increases in $\dot{V}O_{2peak}$. The lack of improvement in aerobic fitness observed by Reilly and White[16] may be related to the number of players involved in the small-sided games,[145] the rules of the game, and/or the playing area in which the conditioning games were conducted.[153] Additionally, indirectly measuring $\dot{V}O_{2peak}$ using the multistage shuttle run test may have influenced the accuracy of such findings.[139] Nevertheless, it was concluded by the authors that small-sided conditioning games were an acceptable substitute for aerobic interval training to maintain fitness during the competitive season. Similarly, Sassi et al.[17] compared the responses of repetitive interval running with small-sided games (4 vs 4 and 8 vs 8) and drills for technical/tactical training in top European league soccer players. Repetitive running consisted of 4 × 1000 m runs, separated by 150 sec of recovery. The authors concluded that small-sided games with the ball could present physiological training stimuli comparable to and sometimes exceeding interval training without the ball. This was demonstrated by the higher heart rates observed during small-sided games (178 ± 7 beats/min) than in the repetitive running bouts (167 ± 4 beats/min). This finding supports the earlier work of Reilly and Ball,[148] who showed a higher energetic cost of dribbling with a ball compared with normal running. The authors found, irrespective of speed, an added cost of 5.2 kJ/min when a ball was involved and an increase in blood lactate concentration. Collectively, therefore, these findings suggest that small-sided games are adequate alternatives to traditional repetitive running bouts.

In a similar study, but of longer duration (14 weeks), 29 soccer players trained twice a week with part of the training session devoted to aerobic interval training.[152] Both the sport-specific (n = 14) and generic training (n = 15) groups completed four bouts of exercise lasting 4 minutes, separated with 3 minutes of active recovery (60–70% HR_{peak}), as suggested by Helgerud et al.[5] There was, however, no control group for this study. The mode of exercise for the generic training group was running around a regular soccer pitch at an intensity corresponding to 90–95% HR_{peak}. The sport-specific training group played different small-sided games (3 vs 3 with goal keeper, 2–3 ball touches, 25×35 m field dimensions; 4 vs 4 with goal keeper, 2 ball touches, 40×50 m field; 4 vs 4 and 5 vs 5). The average exercise intensity, expressed as a percentage of HR_{peak}, during the generic training sessions was not different from that achieved during the sport-specific training sessions (90.7±1.2% and 91.3±2.2%, respectively), suggesting that both approaches result in sufficient exercise intensities to promote aerobic adaptation. However, after training, greater increases in $\dot{V}O_{2peak}$ (7%), LT (10%) and exercise economy at LT (2%) were observed in the generic training group. Despite similar training intensity and pre-training $\dot{V}O_{2peak}$ values (56–58[152] and 58 mL/kg/min[16]), these increases are substantially greater than those previously reported by Reilly and White.[16] The differences observed are most probably due to the greater duration of the training intervention (14 vs 6 weeks). Nevertheless, it should be noted that the improvements reported by Impellizzeri et al.[152] are lower than the corresponding 10%, 16% and 7% increases in $\dot{V}O_{2peak}$, LT and exercise economy, respectively, reported by Helgerud et al.[5] after only 8 weeks of interval training. This could be explained by different initial fitness levels and possibly the type of training programme employed by Helgerud et al.[5] prior to the training intervention.

More importantly, in addition to the measured increases in aerobic fitness, Impellizzeri et al.[152] observed substantial changes in several measures of match performance, for both training groups, albeit derived from one (post-training) match analysis. Most relevant to soccer performance were the increases in the time spent performing high-intensity activities, 22.8% and 25.5% for the generic and sport-specific training groups, respectively. The amount of high-intensity activity performed is generally accepted to differentiate top-level professional players from those of a lower standard, and therefore it is an important parameter to consider.[25] In addition, high-intensity activities are generally associated with critical moments in a soccer match, such as scoring a goal. The total distance covered during match play also increased post-training, by 6.4% and 4.2% for the generic and sport-specific training groups, respectively. However, these increases (594 and 399 m) were lower than the remarkable 1716 m previously reported by Helgerud et al.[5] While soccer players generally do not run around on the pitch without purpose or intent, the total distance travelled during a soccer match is a poor indicator of soccer performance.[30] The differences in the improvements in total distance travelled in these studies could have been influenced by several factors, including: (i) the importance of the match; (ii) the skill level of the opposition; (iii) seasonal variation;[43,44] and (iv) the tactical approach used. Other match performance characteristics evaluated included the time spent performing low-intensity activities, which increased by 18.2% for the generic training group and by 7% for the sport-specific training group. This difference is difficult to explain, given that both groups performed active recovery – jogging at 60–70% HR_{peak}. Active recovery during training would essentially induce improvements in exercise economy at the intensities associated with recovery, therefore allowing greater ground to be covered during a match situation at lower intensities. Finally, time spent walking decreased in both groups by a similar amount (9.3% and 8.2% for the generic and sport-specific training groups, respectively). This suggests that players were more 'engaged' in the game. In summary, the findings of Impellizzeri et al.[152] demonstrate that sport-specific aerobic conditioning has minimal advantages over traditional interval-based aerobic conditioning, with respect to increases in aerobic fitness and, most importantly, match performance characteristics. It should be noted that these findings refer only to soccer. Future studies could examine the influence of combining both sport-specific and traditional aerobic conditioning methods within the same training programme and its subsequent effects on match performance characteristics.

5.2 Traditional and Sport-Specific Aerobic Conditioning and Other Sports

In other football codes, interval training using distances and activities specifically related to competition has been reported. For example, in rugby league, activities such as (i) moving up and back over 10 m for periods of 30–90 sec; (ii) repeat tackling efforts on a bag for 5–10 repetitions; and (iii) sprint efforts over distances of 5–60 m have been recommended, with varying exercise-to-rest ratios.[143] Recently, similar skill-based conditioning games have been compared with traditional conditioning activities in rugby league.[18] Skill-based conditioning consisted of games designed to develop passing, catching and ball-carrying technique, tackling technique, scrambling defence and supportive play, play-the-ball speed, defensive line speed and shape, and ball control. Traditional conditioning sessions were not strictly aerobic in nature and consisted of speed, muscular power, agility and aerobic endurance training common to rugby league. Both groups performed twice-weekly training sessions, of approximately 60–100 min duration, over a 9-week in-season training period. Training intensity was estimated using a modified rating of perceived exertion scale:[154] no significant differences were detected between conditioning groups. Gabbett[18] compared the performance of rugby league athletes participating in skill-based conditioning games versus traditional conditioning, and observed similar increases in predicted $\dot{V}O_{2peak}$ (4.7% and 5.2%, respectively). In terms of performance, both groups won 75% of their games during the training period; however, the teams adopting the skill-based conditioning games approach scored significantly more points per game (61%; $p < 0.05$) and conceded fewer points per game compared with traditional training methods. As previously mentioned for soccer,[7] these differences could be influenced by several factors, including, but not limited to, ground and environmental conditions, injuries and the quality of the opposition.[18] However, skill-based conditioning games have been recommended for team sport athletes as a method of developing skills under pressure and fatigue.[155,156] As such, the sport-specific training regimen employed by Gabbett[18] appeared to transfer better into the competitive rugby league environment, enhancing decision-making while under pressure from opposition and ultimately resulting in greater points scored and fewer points conceded. However, many factors can influence the points differential during rugby league, making this method of assessing the impact of sport-specific aerobic conditioning methods on team performance somewhat unreliable. Therefore, future research could examine the effect of traditional and sport-specific aerobic conditioning methods on standardized running protocols that reflect the competition demands of rugby league.

5.3 Summary

It appears that sport-specific and traditional aerobic conditioning approaches are equivocal in soccer and rugby league, in terms of developing aerobic fitness and match performance. As expected, the magnitude of response in most instances is dependent upon the intensity, frequency and duration of training, as well as the total duration of the training programme and the initial fitness level of the athletes involved. Sport-specific conditioning games may be slightly more strenuous than traditional training approaches, as demonstrated by elevated heart rate responses, which may potentially evoke greater improvements in cardiovascular function and subsequently aerobic fitness. These higher responses can be attributed to the additional physical demands imposed on players during activities such as small-sided games,[157] where the use of a ball increases the metabolic cost of performing any given activity, and possibly increased motivation and enthusiasm of players when completing sport-specific conditioning games/drills. Unfortunately, many studies are hampered by a small sample size, lack of a control group, and indirect measures of aerobic fitness.

6. Conclusion

It has been well established (especially in basketball, rugby union and soccer) that team sport athletes require a well developed level of aerobic fitness, in order to maintain repeated high-intensity efforts and to recover adequately between such activities throughout a typical game (40–90 min). Research to date suggests that these adaptations can be achieved by regularly performing aerobic conditioning. Traditional aerobic conditioning, with minimal changes of direction and no skill component, has been demonstrated to effectively increase aerobic function within a 4- to 10-week period in team sport players. More importantly, traditional aerobic conditioning methods have been shown to increase sport performance substantially, with increases in total distance covered and the number of sprints performed during a match.

Many professional team sports require the upkeep of both aerobic fitness and sport-specific skills during the competitive season. With classic team sport trainings being shown to evoke marginal increases/decreases in aerobic fitness, sport-specific aerobic conditioning methods have been designed to allow adequate intensities to be achieved to induce improvements in $\dot{V}O_{2peak}$. Such activities have incorporated movement- and skill-specific tasks, such as small-sided games and dribbling circuits.

Sport-specific conditioning methods have been demonstrated to promote increases in $\dot{V}O_{2peak}$; however, little research to date has addressed the subsequent effects on game performance. The effectiveness of sport-specific conditioning appears to be influenced by the skill level of the athlete, where those with a lower skill level may not be able to maintain the skill or drill at a suitable intensity to promote the desired aerobic adaptations. Current fitness must also be considered. Players with already high levels of fitness may easily achieve the desired physical load during small-sided games and thus not achieve a training effect. Skill- and fitness-related issues can be overcome by manipulating conditions such as player numbers, field dimensions, game rules and coach encouragement: smaller playing numbers, larger playing areas and coach encouragement tend to increase the metabolic loading of small-sided games. When traditional and sport-specific conditioning approaches are compared, results are equivocal. Both approaches promote similar increases in aerobic fitness and sport performance when training intensity and volume are constant. Definitely the most important benefit of performing sport-specific conditioning is that it allows for both aerobic fitness and game skills to be developed simultaneously.

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Correspondence: Dr *Andrew E. Kilding*, School of Sport and Recreation, AUT University, Private Bag 92006, Auckland 1020, New Zealand.
E-mail: andrew.kilding@aut.ac.nz

