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Yin and yang, or peas in a pod? Individual-sport versus team-sport athletes and altitude training

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ABSTRACT

The question of whether altitude training can enhance subsequent sea-level performance has been well investigated over many decades. However, research on this topic has focused on athletes from individual or endurance sports, with scant number of studies on team-sport athletes. Questions that need to be answered include whether this type of training may enhance team-sport athlete performance, when success in team-sport is often more based on technical and tactical ability rather than physical capacity per se.

This review will contrast and compare athletes from two sports representative of endurance (cycling) and team-sports (soccer). Specifically, we draw on the respective competition schedules, physiological capacities, activity profiles and energetics of each sport to compare the similarities between athletes from these sports and discuss the relative merits of altitude training for these athletes. The application of conventional live-high, train-high; live-high, train-low; and intermittent hypoxic training for team-sport athletes in the context of the above will be presented. When the above points are considered, we will conclude that dependent on resources and training objectives, altitude training can be seen as an attractive proposition to enhance the physical performance of team-sport athletes without the need for an obvious increase in training load.

BACKGROUND

A common refrain in altitude training papers in recent years has been that despite years of research no consensus exists on whether altitude training enhances sea-level performance. There are various models for sport science research, and an important first step is to identify a real-world problem or issue faced by athletes and coaches.[1] This review will attempt to assist team-sport coaches and scientists in deciding on whether to use altitude training with their athletes based on a review and comparison of the literature on a group of athletes that it is largely accepted can benefit from altitude training.

Many researchers are convinced that altitude training can confer small, yet meaningful enhancements in sea-level performance.[2–18] This is only true, of course, where athletes enter altitude training free from illness and fatigue and thus capable of acclimatisation.[19] This opinion is not ubiquitous, with some researchers citing the lack of double-blind, placebo-controlled studies to conclude that this method is truly effective.[20] No doubt this question will continue to be debated for some time, as our knowledge increases through the collective efforts of several research groups.[3 19 21–24] The majority of studies on altitude training have used 'individual sport' or 'endurance' athletes to establish the efficacy of this training,[2–18] which leads to another portion of this question that has received scant attention in the literature until now,[22 25–27] that is, can altitude training benefit team-sport athlete physical performance? A series of well-controlled studies with matched training content will ultimately help answer this question. Another important consideration is whether all team-sport athletes actually need to improve their fitness or at least whether improvements effectively translate into better performance during games.[28] In contrast to cycling for example, the outcomes in team sports rely heavily on technical/tactical actions, which may be less dependent on physical fitness. However, the supposed physiological and performance benefits with altitude training may be gained with only limited alteration of the technical/tactical training programme, together with the maintenance of sea level training loads. During an altitude camp, the adaptations are triggered throughout continued exposure to hypoxia; there is no need for extra fitness sessions that may compromise recovery and/or increase injury risk. This article will outline the key differences and similarities between individual-sport and team-sport athletes, the competitions they are involved in, how they train, their activity profiles in competition and conclude with a view on the likely success of altitude training for these athletes drawing on the few studies investigating this question. For simplicity, this article will focus on cyclists and soccer athletes as representative of individual-sport and team-sport athletes, respectively. This is in part convenient, but also reflective of the weight of scientific literature available on these two groups. The physiological determinants of team sports and implications for altitude training will be dealt with elsewhere in this supplement[29 30] and have been raised in a previous review.[22]

STRUCTURE OF COMPETITION

Analysis of the competition schedule differences between cyclists and soccer athletes is essential in deciding if altitude training is even feasible. The training and competition year of cyclists and soccer athletes are very different. Professional road cyclists can have up to approximately 100 racing days per season, sometimes starting in January[31] and continuing through to October for competition at World Championships.[32 33] Within this period, and depending on the type of rider, cyclists compete in

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1-day races, ~1–2-week tours with consecutive days of racing,[31] or even 'Grand Tours' of 21 days duration with only 1–2 days of rest and approximately 3500–4000 km of racing, interspersed with rest and training.[32 34–36] Tour races typically include a time-trial, and varying amounts of flat or climbing stages, possibly including mountain-top finishes at moderate altitude.[32 34–36] The activity profile of cyclists varies considerably according to the type of stage and terrain encountered in these stages.[32 33 36–38]

Each stage of a multiday race is effectively its own race, with some cyclists attempting to win individual stages, others wanting the fastest overall time for the race to become the 'General Classification', or *overall* winner. Each rider is part of a team, and has a defined role, as leader, helper (domestiqué), or even opportunist to attempt individual stage victories. The activity profile of the cyclists therefore changes dramatically depending on the role of the cyclist in each stage or race.[33 38]

Contrast the cycling season to that of elite soccer players, where the European season starts in August and continues through to May, or longer, depending on National team commitments of individual players.[39] All official soccer matches are played over approximately 90 min[40] on a grass surface, with similar field dimensions.[39] While there are players with specific roles, playing in specific positions,[41 42] excluding the goalkeeper, the differences in activity profile between positions may not be as large, and importantly not as meaningful,[43] as between discrete stages or roles in cycling tour races.[31 33 38 40 44] An obvious difference between the two sports is that cycling races are held over a certain distance, where the time to complete the task varies, where soccer matches are played over a fixed time and the distance covered by individuals varies.[33 40]

Another important differentiation between cycling and soccer is that cyclists sometimes use lesser ranked races as 'training' for targeted events later in the season. Soccer athletes, on the other hand, are required to focus on match-to-match wins, as each match in the regular season, sometimes several games per week,[45 46] counts equally to the Premiership table and the ultimate success of the team. In addition, soccer teams may compete in several different competitions concurrently, for example, Premiership, domestic cup, Champions League.

ACTIVITY PROFILE DURING COMPETITION

Key differences

Given the wide range of total time for cycling races versus soccer matches, and the differing forms of locomotion used, it is not at all surprising that the total distance covered by athletes of the two respective sports varies considerably. For example, allowing for some variance due to the methods used to measure distance, soccer athletes may cover between 9–13 km in a match,[41 47] whereas their cycling counterparts can race for up to 300 km. Official soccer matches are mandated to be 90 min plus stoppage time. In some knock-out competitions, if the match is tied after full time an additional 2×15 min halves of extra time are played, followed by a penalty shootout if the match has still not been decided. By contrast, some cycling races can last up to 7 h.

The average energy expenditure of soccer athletes during a match is approximately 1.02 kJ/kg/min,[47] which equates to a total energy expenditure during a 90 min match for an athlete of typical mass[47] of ~7000 kJ. For cyclists, during the long mountain stages of the Tour de France, the mean energy expenditure per day is 28 500 kJ/day.[48] Cyclists thus have much higher energy requirements per day compared to soccer players, especially during the hardest days of competition.[49]

Key similarities

So far, the differences between cycling and soccer athletes have been highlighted, but there are a number of important similarities as well. Neither cyclists nor soccer players compete at a constant intensity—that is, both are involved in stochastic events. Even in a cycling time-trial, pacing strategies, variations in terrain and environmental factors such as wind speed and direction dictate a varied application of power by the rider.[37] Typical of cycling and soccer, athletes spend a large amount of time at low intensity during competition.[31 33 38 40 47] In mass-start cycling races over flat terrain, approximately 89% of stages are spent at low–moderate intensity.[38] In English Premier League soccer matches, time spent in the lower (<14.4 km/h) activity bands is approximately 85%.[41]

Despite the majority of competition being spent at submaximal intensity in both sports, the higher intensity activities are often aligned with key events that determine the outcome of respective competitions. For example, when establishing a breakaway in cycling, there are numerous 5–15 s efforts > ~9.5–14 W/kg.[50] Further, during criterium racing, there are a higher number of sprints compared to road stages due to the specific requirement of repeatedly accelerating out of corners.[31] Finally, the finish of a cycling race typically results in a sprint between two and more riders, or at least a sustained high-intensity effort, and the outcome of that sprint decides the outcome of the race.[31 38] In professional soccer, straight sprints represent the most frequent action immediately prior to goal scoring.[51] Figure 1 depicts crank power data collected on an SRM power metre (Schoberer Rad Messtechnik, SRM Training System) from an International Criterium Race (multiple laps of a short circuit) and velocity data from 10 Hz global positioning system (GPS, Catapult Innovations V4) from one-half of an International Youth Soccer Friendly Match.[52] The extent of the accelerations undertaken by each type of athlete is evident, as is the underlying high volume of low-intensity activity. Energetically, these high-intensity tasks are largely fuelled by phosphocreatine (PCr) degradation, and the resynthesis of this is a purely aerobic task. It is therefore possible that altitude training could enhance this capacity in cycling as well as soccer athletes.

PHYSIOLOGICAL ADAPTATION

The higher volume of activity in cycling compared to soccer manifests from successful cyclists having a higher aerobic power than their soccer counterparts. For example, the maximum oxygen uptake of cyclists competing in the Tour de France is between 70 and 86 mL/kg/min[36]; whereas that of elite soccer players is substantially lower, between 50 and 74 mL/kg/min.[40 53 54] This opens the possibility that cyclists may have reached a higher percentage of their genetic potential for aerobic power enhancement than soccer players, and therefore, are less suited to gains from altitude training,[55] although this seems unlikely as other elite endurance athletes make gains from this type of training.[5 13 14] Also, as the magnitude of haemoglobin (Hb) increase may be related with baseline haemoglobin mass (Hb_{mass}),[56] soccer players may more probably present increased Hb_{mass} than elite cyclists. Team-sport athletes are generally responsive to short-term intensified training.[57 58] In a similar team sport (Australian rules football), the Yo-Yo Intermittent Recovery Test two (Yo-YoIR2) score mediates the amount of high-velocity running undertaken by elite footballers, how many times they receive possession of the ball in matches and the coach ratings of player performance.[59] It is however worth noting that

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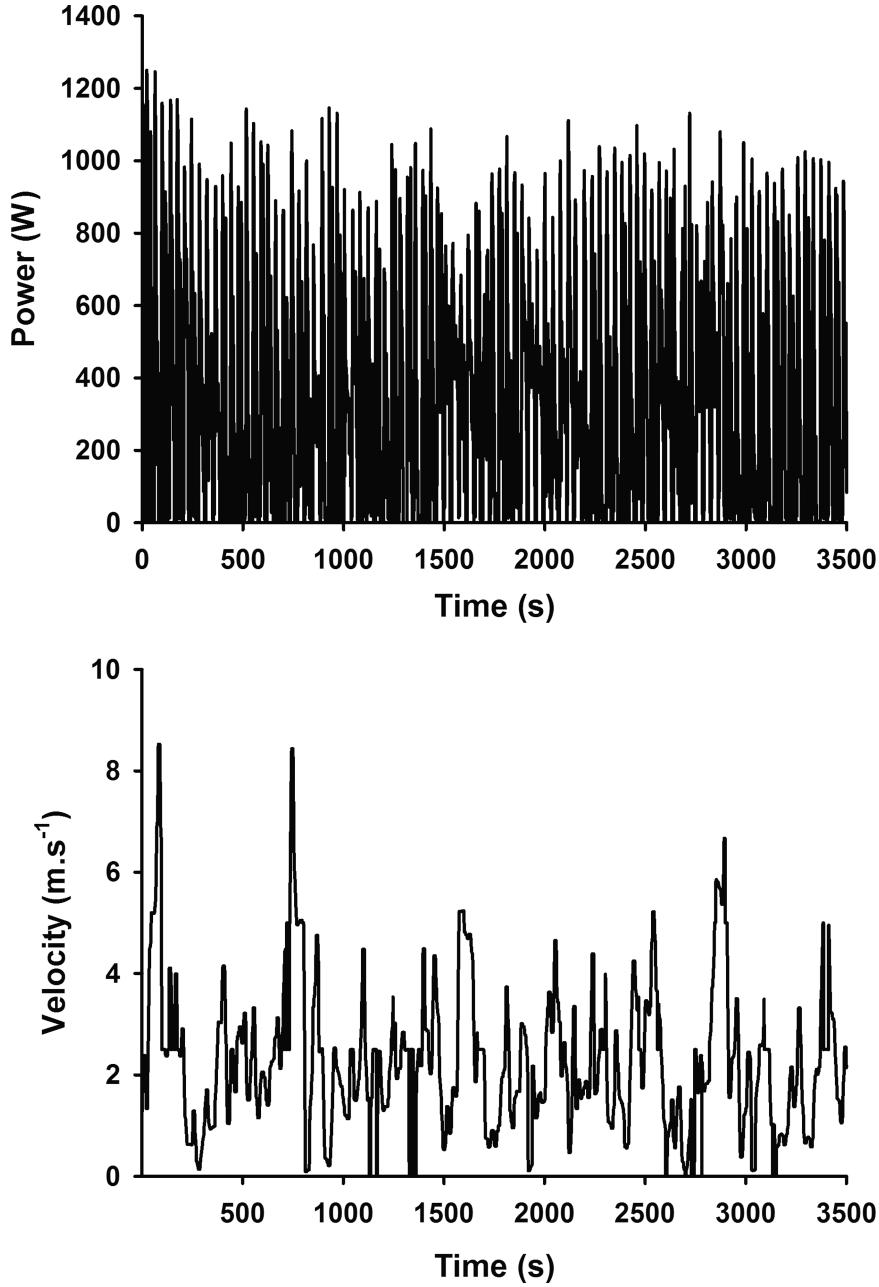

Figure 1 Power profile of a professional cyclist from an International Criterium Race (A) and velocity trace from an elite youth soccer player during an international Friendly Match (B).

the importance of fitness for match running performance and match outcomes is not as straightforward as it is in cycling.[60] Players' physical activity during games is largely driven by game tactics[61] and outcomes[62] which have a greater impact than physical fitness per se. When considering individual players, clear improvements in maximal aerobic power and sprint speeds are not consistently associated with increased activity during games.[28] The fittest and fastest players do not consistently perform at a greater intensity on the field,[63 64] probably because the demands of the game constrain their activity. Along these lines, there is no association between the decrement in match running performance during the second half and physical capacities.[65] Since all the players may not exercise at maximal levels the whole game, and because of the pacing strategies they may employ, the importance of a very well developed fitness level may not always be high. In contrast, it is clear that an elevated fitness level may translate into reduced relative intensity during games,[65] which may in turn indirectly improve technical efficiency with the ball.[66]

To accelerate a body is a metabolically demanding task and requires the athlete to overcome inertia and environmental forces, independent of the sport.[47 67] Thus, while the overall volume of activity is higher in cycling than soccer, the relative contributions of low-velocity and high-velocity activity in each implies that the relative energetic demands may be similar. Energetically, PCr is the major substrate contributing to short high-intensity efforts and the resynthesis of PCr is rate-limiting for repeated high-intensity activity such as that occurring in cycling races[31 38] and soccer matches.[68 69] As the resynthesis of PCr is entirely aerobic, cyclists as well as soccer players may benefit from training regimes that enhance aerobic processes. Whether such benefits are definitely worthwhile in regard to the financial cost, training load and actual impact during games is another question.

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ALTITUDE TRAINING FOR TEAM-SPORTS

There are sufficient similarities between cycling and soccer outlined above to conclude that training regimes that enhance the aerobic power of endurance athletes may also be beneficial for team-sport athletes. The challenge for team-sport athletes wanting to engage in altitude training is finding time in a busy schedule to dedicate to such training without compromising the tactical and technical training required. For example, skills training at altitude[70] will be affected by the altered flight characteristics of the ball and reduced training intensity.[71]

Most studies have concentrated on the haematological benefits of altitude training. The live-high, train-high (LHTH) method, where athletes train and reside at altitude increases Hb_{mass},[2 3] and may,[72] or may not[73 74] increase maximum oxygen uptake and work capacity on return to sea level. Successful altitude training camps utilising LHTH methodology typically require athletes to be resident at altitude for 3–4 weeks.[75] In a typical soccer preseason, that is, 8 weeks in duration,[39] a 4-week altitude camp at terrestrial altitude is unlikely to be supported by many managers. Moreover, many countries simply lack the appropriate geography and/or training facilities at altitude to seriously entertain the LHTH method. However, not all team-sports have a short preseason like soccer and the LHTH method has recently been successfully used to enhance the physical capacity of Australian rules football athletes, as one 19-day period of a ~15-week preseason conditioning phase.[27] This method has also recently been used in elite youth soccer players who spent 12 days at 3600 m, with a very large subsequent increase in Yo-Yo performance, but also decline in sprinting ability with some illness at this altitude reported.[76] A recent meta-analysis of Hb_{mass} confirms that total Hb_{mass} increases at approximately 1% per 100 h of hypoxia, so that a 2-week camp would also probably be beneficial to aerobic power, albeit that individuals may vary substantially more or less than the group mean response.[77] A 2-week camp is therefore a more realistic option compared with a 4-week camp in a busy preseason preparation. However, since the additional improvements in physical performance gained with altitude training were rather small (+1.5%, with large individual responses),[27] and considering the importance of speed qualities in team-sports,[51] the actual benefit of such camps can be questioned and should be viewed with a cost/benefit approach. In this perspective, as several professional teams regularly travel abroad for training camps; it may then be a cost-effective option to implement such camp at an altitude venue.

An altitude training method that might help overcome some of the geographical and training issues associated with live-high, train-low (LHTL) method. Without entering into the debate regarding the importance of hypobaric versus normobaric hypoxic stimuli,[23] the normobaric LHTL method also probably increases Hb_{mass}[3 14 78] and subsequent performance.[5 13 14 79] If teams had suitable facilities, athletes could train at their normal location, and reside at simulated altitude. However, few teams have access to facilities with capacity to house all of their athletes, making the LHTL method difficult for the majority of teams to employ. Additionally, since usual hypoxic rooms might not offer a similar level of comfort as professional soccer players are accustomed to, they might be reluctant to embrace such a training approach. A third method of altitude training available to team-sport athletes involves intermittent hypoxic training (IHT). This method involves short intense exercise sessions of either IHT,[25] or specific repeated sprints in hypoxia (RSH)[80] being conducted under normobaric hypoxic conditions. While also typically requiring specialised equipment or facilities, the IHT method is less expensive and very time-efficient for team-sport athletes, requiring 1–3 1 h sessions per week for 3–4 weeks for adaptation.[81] The effects of IHT on qualities important for team-sport athletes are however equivocal. In one study, anaerobic power measured by a Wingate test increased by ×3 the smallest worthwhile change in performance,[81] but in another did not.[82] Similarly, there was a very large standardised effect on maximum aerobic power in one,[83] but not all[16 81 84] studies using IHT. The total hypoxic stimuli is not sufficient to initiate an erythropoietic response.[84] Encouragingly, RSH was reported to moderately increase repeated-sprint performance,[80] and IHT increased Yo-Yo IR2 performance, the latter using team-sport athletes, with substantial improvement after only 2 weeks of IHT compared to matched controls.

A final issue to consider when deciding which method of altitude training to use, if any, is the potential impact on athletes during sleep. In particular, when sleeping at altitude, 40–50% of athletes exhibit severe disordered breathing, even though their breathing is normal at sea level.[86 87] The impact of this disruption on athletes' daytime function is not yet known, but in untrained adults it impairs alertness, cognitive performance and well-being.[88] With LHTH, it is not possible to avoid disordered breathing during sleep, and any associated consequences, for those who are susceptible. With LHTL, respiratory bands and/or pulse-oximetres can be used on the first few nights at altitude to identify those with disordered breathing, and if their daytime well-being and/or performance are also poor, then they may get more benefit from the camp if they sleep at sea level. With IHT, disordered breathing during sleep is avoided.

Each altitude training method has pros and cons that require serious thought before adopting one method in team-sport athletes. Recently the idea of using multiple methods during a training year has been floated,[89] with the aim of achieving aerobic and anaerobic adaptation through the use of various altitude methods. If hypoxic sleeping as well as training rooms are available at a club, an individualised approach could also be implemented with some players, and/or at specific times during the season (eg, particular players' needs, short block before an important competition, return from injuries). This is an intriguing concept, as the application of the methods described above does result in varying outcomes.

CONCLUSIONS

Team-sport athletes face logistical and timing constraints on when in a training year they could employ altitude training. These athletes could possibly gain more aerobic benefit than their endurance athlete counterparts, but the effect of these gains in terms of match performance is largely unknown and probably context-dependent and player-dependent. However, altitude training can improve specific qualities such as Yo-Yo performance, which might, under certain circumstances, positively impact high-intensity running and involvements with the ball in elite team-sport competition. Thus, dependent on resources and training objectives, altitude training can be seen as an attractive proposition to enhance the physical performance of team-sport athletes without the need for an obvious increase in training load. The potential financial cost of travel, impact on skills training and possible side effects of disordered breathing during sleep, illness and reduced sprinting capacity with LHTH should be considered when choosing a method and the timing of intervention. On balance, there are sufficient similarities between endurance and team-sport athletes to expect that altitude training could enhance some capacities important for team-sport athlete performance.

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What are the new findings?

- Endurance (cycling) and team-sport (soccer) athletes have differing requirements for technical and tactical training—and this is more important in soccer.
- Endurance (cycling) and team-sport (soccer) athletes share sufficient key activity profile and energetic qualities to suggest altitude training could enhance team-sport athlete physical performance.
- Team-sport athletes have limited time in a competitive season to employ altitude training methods.
- Short-duration altitude training with minimal disruption to technical and tactical training will be most probably implemented by team-sport athletes.
- Altitude training may enable team-sport athletes to reach a level of adaptation with a lower training load.

How might it impact on clinical practice in the near future?

This study provides a rationale and framework for clinicians to determine if altitude training might positively influence team-sport athlete performance.

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Competing interests None.

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Yin and yang, or peas in a pod? Individual-sport versus team-sport athletes and altitude training

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