Training and testing physical capacities for elite soccer players.

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Elite soccer players spend a substantial amount of time trying to improve physical capacities, including aerobic endurance and strength and the strength derivatives of speed and power. The average oxygen uptake for international soccer teams ranges from 55 to 68 ml.kg\(^{-1}\).min\(^{-1}\) and the half-squat maximal strength from 120 to 180 kg. These values are similar to those found in other team sports. Recently, it has been shown that the heart's stroke volume is the element in the oxygen chain that mainly limits aerobic endurance for athletes. These findings have given rise to more intensive training interventions to secure high stroke volumes, which, in turn, have proved positive in changing both maximal oxygen consumption and soccer performance in terms of distance covered, contacts with the ball and number of sprints in a game. The training employed has consisted of 4x4-min "intervals" running uphill at 90-95% of maximal heart rate interspersed with 3 min jogging at 70% of maximal heart rate to facilitate removal of lactate.

Research has revealed that a soccer-specific training routine with the ball might be as effective as plain running. Strength training to produce neural adaptations has been effective in changing not only strength in terms of "one-repetition maximum", but also sprinting velocity and jumping height, in elite soccer players without any change in body mass. The same training has also improved running economy and thus aerobic endurance performance. The training regimen used for a European Champions League team was 4x4 repetitions of half-squats with the emphasis on maximal mobilization of force in the concentric action.
Physiological adaptations to soccer specific endurance training in professional youth soccer players.

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BACKGROUND: Improved oxygen uptake improves soccer performance as regards distance covered, involvements with the ball, and number of sprints. Large improvements in oxygen uptake have been shown using interval running. A similar physiological load arising from interval running could be obtained using the soccer ball in training.

OBJECTIVES: The main aim was to study physiological adaptations to a 10 week high intensity aerobic interval training program performed by professional youth soccer players, using a soccer specific ball dribbling track.

METHODS: Eleven youth soccer players with a mean (SD) age of 16.9 (0.4) years performed high intensity aerobic interval training sessions twice per week for 10 weeks in addition to normal soccer training. The specific aerobic training consisted of four sets of 4 min work periods dribbling a soccer ball around a specially designed track at 90-95% of maximal heart frequency, with a 3 min recovery jog at 70% of maximal heart frequency between intervals.

RESULTS: Mean VO₂max improved significantly from 63.4 (5.6) to 69.8 (6.6) ml kg⁻¹ min⁻¹, or 183.3 (13.2) to 201.5 (16.2) ml kg⁻⁰.⁷ five min⁻¹ (p<0.001). Squat jump and counter movement jump height increased significantly from 37.7 (6.2) to 40.3 (6.1) cm and 52.0 (4.0) to 53.4 (4.2) cm, respectively (p<0.05). No significant changes in body mass, running economy, rate of force development, or 10 m sprint times occurred.

CONCLUSION: Performing high intensity 4 min intervals dribbling a soccer ball around a specially designed track together with regular soccer training is effective for improving the VO₂max of soccer players, with no negative interference effects on strength, jumping ability, and sprinting performance.

PMID: 15849290 [PubMed - indexed for MEDLINE]
Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players.

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BACKGROUND: A high level of strength is inherent in elite soccer play, but the relation between maximal strength and sprint and jumping performance has not been studied thoroughly. OBJECTIVE: To determine whether maximal strength correlates with sprint and vertical jump height in elite male soccer players.

METHODS: Seventeen international male soccer players (mean (SD) age 25.8 (2.9) years, height 177.3 (4.1) cm, weight 76.5 (7.6) kg, and maximal oxygen uptake 65.7 (4.3) ml/kg/min) were tested for maximal strength in half squats and sprinting ability (0-30 m and 10 m shuttle run sprint) and vertical jumping height.

RESULT: There was a strong correlation between maximal strength in half squats and sprint performance and jumping height. CONCLUSIONS: Maximal strength in half squats determines sprint performance and jumping height in high level soccer players. High squat strength did not imply reduced maximal oxygen consumption. Elite soccer players should focus on maximal strength training, with emphasis on maximal mobilisation of concentric movements, which may improve their sprinting and jumping performance.

PMID: 15155427 [PubMed - indexed for MEDLINE]
Endurance training and testing with the ball in young elite soccer players.


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BACKGROUND: The aerobic capacity of soccer players substantially influences their technical performance and tactical choices. Thus, the assessment of soccer players' aerobic performance should be of interest for soccer coaches in order to evaluate and improve their endurance training sessions. In this study, we present a new test to assess aerobic performance in soccer by means of a specific dribbling track: the Hoff test. We further determined whether improvement in maximal oxygen uptake was reflected in increased distance covered in the Hoff test.

METHODS: We tested 18 male soccer players (14 years old) both in the laboratory and using the Hoff test before and after 8 weeks of soccer training.

RESULTS: The distance covered in the Hoff test correlated significantly with maximum oxygen uptake, and improved by 9.6% during the 8 week training period, while maximum oxygen uptake and running economy improved by 12 and 10%, respectively. Backward multiple regression showed maximum oxygen uptake to be the main explanatory variable for the distance covered in the Hoff test.

CONCLUSION: The present study demonstrated a significant correlation between laboratory testing of VO(2max) and performance in the Hoff test. Furthermore, training induced improvements in VO(2max) were reflected in improved performance in the Hoff test. We suggest that it should be a goal for active U-15 soccer players to cover more than 2100 metres in the Hoff test, as this requires a VO(2max) of above 200 ml/kg(0.75)/min, which should serve as a minimum in modern soccer.

PMID: 15618335 [PubMed - indexed for MEDLINE]
Endurance and strength training for soccer players: physiological considerations.

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Top soccer players do not necessarily have an extraordinary capacity in any of the areas of physical performance. Soccer training is largely based on the game itself, and a common recruitment pattern from player to coach and manager reinforces this tradition. New developments in understanding adaptive processes to the circulatory system and endurance performance as well as nerve and muscle adaptations to training and performance have given rise to more effective training interventions. Endurance interval training using an intensity at 90-95% of maximal heart rate in 3- to 8-minute bouts have proved to be effective in the development of endurance, and for performance improvements in soccer play. Strength training using high loads, few repetitions and maximal mobilisation of force in the concentric mode have proved to be effective in the development of strength and related parameters. The new developments in physical training have important implications for the success of soccer players. The challenge both for coaches and players is to act upon the new developments and change existing training practice.

Publication Types:

- **Review**

PMID: 14987126 [PubMed - indexed for MEDLINE]
The effect of in-season, high-intensity interval training in soccer players.

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The effects of in-season, high-intensity interval training on professional male soccer players' running performances were investigated. Twenty-two subjects participated in 2 consecutive training periods of 10 weeks. The first period was considered a control period and was compared with a period where 2 high-intensity interval training exercises were included in the usual training program. Intermittent runs consisted of 12-15 runs lasting 15 seconds at 120% of maximal aerobic speed alternated with 15 seconds of rest. Sprint repetitions consisted of 12-15 all-out 40-m runs alternated with 30 seconds of rest. Results from the high-intensity interval training have shown that maximal aerobic speed was improved (+8.1 +/- 3.1%; p < 0.001) and that the time of the 40-m sprint was decreased (-3.5 +/- 1.5%; p < 0.001), whereas no change in either parameters were observed during the control period. This study shows that improvements in physical qualities can be made during the in-season period.

Publication Types:
- Clinical Trial
- Controlled Clinical Trial

PMID: 15320689 [PubMed - indexed for MEDLINE]
Soccer is the most popular sport in the world and is performed by men and women, children and adults with different levels of expertise. Soccer performance depends upon a myriad of factors such as technical/biomechanical, tactical, mental and physiological areas. One of the reasons that soccer is so popular worldwide is that players may not need to have an extraordinary capacity within any of these performance areas, but possess a reasonable level within all areas. However, there are trends towards more systematic training and selection influencing the anthropometric profiles of players who compete at the highest level. As with other activities, soccer is not a science, but science may help improve performance. Efforts to improve soccer performance often focus on technique and tactics at the expense of physical fitness. During a 90-minute game, elite-level players run about 10 km at an average intensity close to the anaerobic threshold (80-90% of maximal heart rate). Within this endurance context, numerous explosive bursts of activity are required, including jumping, kicking, tackling, turning, sprinting, changing pace, and sustaining forceful contractions to maintain balance and control of the ball against defensive pressure. The best teams continue to increase their physical capacities, whilst the less well ranked have similar values as reported 30 years ago. Whether this is a result of fewer assessments and training resources, selling the best players, and/or knowledge of how to perform effective exercise training regimens in less well ranked teams, is not known. As there do exist teams from lower divisions with as high aerobic capacity as professional teams, the latter factor probably plays an important role. This article provides an update on the physiology of soccer players and referees, and relevant physiological tests. It also gives examples of effective strength- and endurance-training programmes to improve on-field performance. The cited literature has been accumulated by computer searching of relevant databases and a review of the authors' extensive files. From a total of 9893 papers covering topics discussed in this article, 843 were selected for closer scrutiny, excluding studies where information was redundant, insufficient or the experimental design was inadequate. In this article, 181 were selected and discussed. The information may have important implications for the safety and success of soccer players and hopefully it should be understood and acted upon by coaches and individual soccer players.
Soccer specific aerobic endurance training.

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**BACKGROUND:** In professional soccer, a significant amount of training time is used to improve players' aerobic capacity. However, it is not known whether soccer specific training fulfils the criterion of effective endurance training to improve maximal oxygen uptake, namely an exercise intensity of 90-95% of maximal heart rate in periods of three to eight minutes. **OBJECTIVE:** To determine whether ball dribbling and small group play are appropriate activities for interval training, and whether heart rate in soccer specific training is a valid measure of actual work intensity. **METHODS:** Six well trained first division soccer players took part in the study. To test whether soccer specific training was effective interval training, players ran in a specially designed dribbling track, as well as participating in small group play (five a side). Laboratory tests were carried out to establish the relation between heart rate and oxygen uptake while running on a treadmill. Corresponding measurements were made on the soccer field using a portable system for measuring oxygen uptake. **RESULTS:** Exercise intensity during small group play was 91.3% of maximal heart rate or 84.5% of maximal oxygen uptake. Corresponding values using a dribbling track were 93.5% and 91.7%. No higher heart rate was observed during soccer training. **CONCLUSIONS:** Soccer specific exercise using ball dribbling or small group play may be performed as aerobic interval training. Heart rate monitoring during soccer specific exercise is a valid indicator of actual exercise intensity.

Publication Types:

- Clinical Trial

PMID: 12055120 [PubMed - indexed for MEDLINE]
Testing soccer players.

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To cope with the physiological demands of soccer, players must be competent across several fitness components. The use of fitness tests in the laboratory and field assist in examining soccer players' capabilities for performance both at the amateur and elite levels. Laboratory tests provide a useful indication of players' general fitness. Accurate test results can be obtained with the use of a thorough methodology and reliable equipment. Laboratory tests are used sparingly during the season because of the time-consuming nature of the tests. Instead, tests are generally carried out at the start and end of the pre-season period to evaluate the effectiveness of specific training interventions. Field tests provide results that are specific to the sport and are therefore more valid than laboratory tests. The reduced cost, use of minimal equipment and the ease with which tests can be conducted make them more convenient for extensive use throughout the season. Although data from laboratory and field tests provide a good indication of general and soccer-specific fitness, individual test results cannot be used to predict performance in match-play conclusively because of the complex nature of performance in competition. Fitness tests in conjunction with physiological data should be used for monitoring changes in players' fitness and for guiding their training prescription.

Publication Types:

- **Review**

PMID: 16195009 [PubMed - indexed for MEDLINE]
Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones.

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Thirty-two untrained men [mean (SD) age 22.5 (5.8) years, height 178.3 (7.2) cm, body mass 77.8 (11.9) kg] participated in an 8-week progressive resistance-training program to investigate the "strength-endurance continuum". Subjects were divided into four groups: a low repetition group (Low Rep, n = 9) performing 3-5 repetitions maximum (RM) for four sets of each exercise with 3 min rest between sets and exercises, an intermediate repetition group (Int Rep, n = 11) performing 9-11 RM for three sets with 2 min rest, a high repetition group (High Rep, n = 7) performing 20-28 RM for two sets with 1 min rest, and a non-exercising control group (Con, n = 5). Three exercises (leg press, squat, and knee extension) were performed 2 days/week for the first 4 weeks and 3 days/week for the final 4 weeks. Maximal strength [one repetition maximum, 1RM), local muscular endurance (maximal number of repetitions performed with 60% of 1RM), and various cardiorespiratory parameters (e.g., maximum oxygen consumption, pulmonary ventilation, maximal aerobic power, time to exhaustion) were assessed at the beginning and end of the study. In addition, pre- and post-training muscle biopsy samples were analyzed for fiber-type composition, cross-sectional area, myosin heavy chain (MHC) content, and capillarization. Maximal strength improved significantly more for the Low Rep group compared to the other training groups, and the maximal number of repetitions at 60% 1RM improved the most for the High Rep group. In addition, maximal aerobic power and time to exhaustion significantly increased at the end of the study for only the High Rep group. All three major fiber types (types I, IIA, and IIB) hypertrophied for the Low Rep and Int Rep groups, whereas no significant increases were demonstrated for either the High Rep or Con groups. However, the percentage of type IIB fibers decreased, with a concomitant increase in IIAB fibers for all three resistance-trained groups. These fiber-type conversions were supported by a significant decrease in MHCIIb accompanied by a significant increase in MHCIIa. No significant changes in fiber-type composition were found in the control samples. Although all three training regimens resulted in similar fiber-type transformations (IIB to IIA), the low to intermediate repetition resistance-training programs induced a greater hypertrophic effect compared to the high repetition regimen. The High Rep group, however, appeared better adapted for submaximal, prolonged contractions, with significant increases after training in aerobic power and time to exhaustion. Thus, low and intermediate RM training appears to induce similar muscular adaptations, at least after short-term training in previously untrained subjects. Overall, however, these data demonstrate that both physical performance and the associated physiological adaptations are linked to the intensity and number of repetitions performed, and thus lend support to the "strength-endurance continuum".

PMID: 12436270 [PubMed - indexed for MEDLINE]
The yo-yo intermittent recovery test: physiological response, reliability, and validity.


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PURPOSE: To examine the physiological response and reproducibility of the Yo-Yo intermittent recovery test and its application to elite soccer. METHODS: Heart rate was measured, and metabolites were determined in blood and muscle biopsies obtained before, during, and after the Yo-Yo test in 17 males. Physiological measurements were also performed during a Yo-Yo retest and an exhaustive incremental treadmill test (ITT). Additionally, 37 male elite soccer players performed two to four seasonal tests, and the results were related to physical performance in matches. RESULTS: The test-retest CV for the Yo-Yo test was 4.9%. Peak heart rate was similar in ITT and Yo-Yo test (189 +/- 2 vs 187 +/- 2 bpm), whereas peak blood lactate was higher (P < 0.05) in the Yo-Yo test. During the Yo-Yo test, muscle lactate increased eightfold (P < 0.05) and muscle creatine phosphate (CP) and glycogen decreased (P < 0.05) by 51% and 23%, respectively. No significant differences were observed in muscle CP, lactate, pH, or glycogen between 90 and 100% of exhaustion time. During the precompetition period, elite soccer players improved (P < 0.05) Yo-Yo test performance and maximum oxygen uptake ([O2max]) by 25 +/- 6 and 7 +/- 1%, respectively. High-intensity running covered by the players during games was correlated to Yo-Yo test performance (r = 0.71, P < 0.05) but not to [O2max] and ITT performance. CONCLUSION: The test had a high reproducibility and sensitivity, allowing for detailed analysis of the physical capacity of athletes in intermittent sports. Specifically, the Yo-Yo intermittent recovery test was a valid measure of fitness performance in soccer. During the test, the aerobic loading approached maximal values, and the anaerobic energy system was highly taxed. Additionally, the study suggests that fatigue during intense intermittent short-term exercise was unrelated to muscle CP, lactate, pH, and glycogen.

Publication Types:

- Clinical Trial

PMID: 12673156 [PubMed - indexed for MEDLINE]
PURPOSE: To investigate the relationship between physical fitness and team success in soccer, and to test for differences in physical fitness between different player positions.

METHODS: Participants were 306 male soccer players from 17 teams in the two highest divisions in Iceland. Just before the start of the 1999 soccer season, the following variables were tested: height and weight, body composition, flexibility, leg extension power, jump height, and peak O2 uptake. Injuries and player participation in matches and training were recorded through the 4-month competitive season. Team average physical fitness was compared with team success (final league standing) using a linear regression model. Physical fitness was also compared between players in different playing positions.

RESULTS: A significant relationship was found between team average jump height (countermovement jump and standing jump) and team success (P = 0.009 and P = 0.012, respectively). The same trend was also found for leg extension power (P = 0.097), body composition (% body fat, P = 0.07), and the total number of injury days per team (P = 0.09). Goalkeepers demonstrated different fitness characteristics from outfield players. They were taller and heavier, more flexible in hip extension and knee flexion, and had higher leg extension power and a lower peak O2 uptake. However, only minor differences were observed between defenders, midfield players, and attackers.

CONCLUSION: Coaches and medical support teams should pay more attention to jump and power training, as well as preventive measures and adequate rehabilitation of previous injuries to increase team success.

PMID: 14767251 [PubMed - indexed for MEDLINE]
Soccer specific testing of maximal oxygen uptake.

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AIM: Endurance capacity in soccer players is important. A soccer specific test for direct measurement of maximal oxygen uptake does, however, not exist. The aim of this study was to evaluate maximal oxygen uptake in a soccer specific field test, compared to treadmill running. METHODS: Ten male soccer players (age 21.9+/−3.0 years, body mass 73.3+/−9.5 kg, height 179.9+/−4.7 cm) participated in the study, and 5 endurance trained men (age 24.9+/−1.8 years, body mass 81.5+/−3.7 kg, height 185.6+/−3.1 cm) took part in a comparison of the portable and the stationary metabolic test systems. The soccer players accomplished a treadmill test and a soccer specific field test containing dribbling, repetitive jumping, accelerations, decelerations, turning and backwards running. RESULTS: Maximal oxygen uptake was similar in field (5.0+/−0.5 L x min(−1)) and laboratory (5.1+/−0.7 L x min(−1)) tests, as were maximal heart rate, maximal breathing frequency, respiratory exchange ratio and oxygen pulse. Maximal ventilation was 5.4% higher at maximal oxygen uptake during treadmill running. CONCLUSION: These findings show that testing of maximal oxygen uptake during soccer specific testing gives similar results as during treadmill running, and therefore serves as a valid test of maximal oxygen uptake in soccer players.

PMID: 12853894 [PubMed - indexed for MEDLINE]
Physiological assessment of aerobic training in soccer.
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Physiological assessment of soccer training usually refers to the measurement of anatomical, physiological, biochemical and functional changes specific to the sport discipline (training outcome). The quality, quantity and organization of physical exercises (training process) are, on the other hand, usually described by the external work imposed by the coach on his or her athletes. In this review, we demonstrate that this approach is not appropriate in soccer, as training is often based on group exercises. The physiological stress (internal load) induced by such training often differs between individuals. Here, we present some physiological laboratory-based tests and field tests used to evaluate training outcomes in soccer, together with methods based on heart rate and perceived exertion to quantify internal load imposed during training. The integrated physiological assessment of both training outcome and process allows researchers: (1) to improve interpretation of physical tests used to verify the effectiveness of training programmes; (2) to evaluate the organization of the training load in order to design periodization strategies; (3) to identify athletes who are poor responders; (4) to control the compliance of the training completed to that planned by the coach; and (5) to modify the training process before the assessment of its outcome, thus optimizing soccer performance.

Publication Types:
- Review
- Review, Tutorial

PMID: 16195007 [PubMed - indexed for MEDLINE]
AIM: The aims of the current study were, firstly, to quantify the motion characteristics of professional youth soccer players and, secondly, to develop and validate a soccer-specific exercise protocol (SSEP). METHODS: The motion characteristics of 12 first team members and 12 scholars (under 19s), signed to an English Premiership club were determined via motion analysis. Motion profiles from the analysis were then used to develop a SSEP for a non-motorised treadmill. Validity of the protocol was checked with 6, healthy, male soccer players who completed the SSEP and, on a separate occasion, a soccer match. Heart rates were recorded during both trials, in addition, capillary blood and expired air samples were taken, and RPE recorded, during the SSEP. RESULTS: Youth team players covered 10274 +/- 609 m, compared to 9741 +/- 882 m by the first team players (t=1.72, p>0.05; 95% CI for the difference = -1174 m to 109 m). The trend for greater mean distance covered by youth players could be attributed to the distances covered while jogging and running. Mean heart rate response was 166 +/- 9 beats x min(-1) during match play and 166 +/- 12 beats x min(-1) during the SSEP (t=0.164, p>0.05). Mean VO(2) during the SSEP was 70 +/- 3% of VO(2max). Blood lactate concentration fell from a mean value of 5.37 +/- 1.15 mmol x L(-1) during the first half to 4.74 +/- 1.25 mmol x L(-1) during the 2(nd) half (t=2.52, p<0.05). CONCLUSION: The findings of this study suggest that the protocol developed induced a similar physiological load to soccer match play and provides the opportunity to study the physiological demands of soccer.

Publication Types:

- Validation Studies

PMID: 15181385 [PubMed - indexed for MEDLINE]
Competitive soccer engages many of the body's systems to a major extent. The musculoskeletal, nervous, immune and metabolic systems are stressed to a point where recovery strategies post-exercise become influential in preparing for the next match. Intense activity at a 7-day training camp causes participants to experience lowered concentrations of non-killer cells and T-helper cells. Two consecutive games in 24 h produce disturbances in the testosterone-cortisol ratio. When competitive schedules are congested, the recovery process should be optimized for performance capabilities to be restored to normal as soon as possible. There is evidence that glycogen stores are reduced near to depletion at the end of a soccer game and that a diet high in carbohydrates can aid recovery. Water alone is not the best means of restoring body fluids, since carbohydrate-electrolyte drinks display better intestinal absorption and reduce urine output. Some relief from muscle soreness may be achieved by means of a warm-down. Deep-water running regimens can replace conventional physical training in the days after competition. Massage, cryotherapy and alternative therapies have not been shown to be consistently effective. It is concluded that optimizing recovery post-exercise depends on a combination of factors that incorporate a consideration of individual differences and lifestyle factors. The procedures to facilitate recovery processes should start immediately the game or training finishes. Match administrators and tournament planners should consider the stressful consequences for players in periods of congested fixtures and alleviate the physiological strain as far as possible by allowing 72 h between competitive games. This frequency of competition is unlikely to be sustainable in the long term.
Strength:

Almaasbakk, B. & Hoff, J., (1996), Coordination, the determinant of velocity specificity, Journal of Applied Physiology, 80(5): 2046-2052


**Strength training effects on endurance performance:**


Cardiovascular adaptations:


Other research:


In preparation:


Helgerud J, Fjellheim D and Hoff J. Maximal oxygen uptake attained in running, cycling and ice skating in elite hockey players. (In preparation).


Projekts in progress:

Helgerud J, Rognmo Ø, Slørdahl SA and Hoff J. High vs low intensity aerobic endurance training effects on angina pectoris.

Helgerud J, Rognmo Ø, Slørdahl SA and Hoff J. Additional O2 fraction breathing effects on trainability in patients with angina pectoris.