総　説

Blood Lipids and Lipoproteins in Soccer Players

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サッカー選手の血中脂質およびリポタンパク質

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要　旨

本研究の目的は、関連した文献から１）サッカー選手の血清脂質およびリポタンパク質に関する横断的研究を食事や栄養素等摂取量、肥満、喫煙、アルコール摂取量、月経周期、競技ポジションなどの潜在的な交絡因子を含めて検討し、２）90分間のサッカー競技の血清脂質およびリポタンパク質に対する急性効果、３）競技者やレクリエーションとして行っている者の定期的なサッカートレーニングが血清脂質およびリポタンパク質に対する効果につい検討することである。サッカー選手の血中脂質における最も一致した見解は、高比重リポタンパクコレステロール（HDL–C）が対照群よりも高値を示すことである。血中脂質およびリポタンパク質における90分間のサッカーの試合の急性効果に関する研究では、特に血漿量の変化を補正する必要がある。定期的なサッカートレーニングを行えば、異なる年齢層において総コレステロール、トリグリセリド、低比重リポタンパクコレステロール（LDL–C）を減少させ、HDL–C を増加させることができる。訓練していない男女のレクリエーションとしてのサッカートレーニングにおける血中脂質への効果に関する最も一致した見解は、LDL–C および/または LDL–C/ HDL–C 比が低下することである。サッカー選手における血中脂質およびリポタンパク質の変化は、リポタンパク質リパーゼ、レシチン：コレステロールアシルトランスフェラーゼおよび肝性リパーゼの活性レベルの変化によるものである可能性が考えられる。サッカー選手における今後の研究は、血中脂質およびリポタンパク質が変化するメカニズムに向けられる必要がある。これらの研究では特に知見が不足している女性や青年、若年成人に焦点を当てるべきである。

キーワード

脂質、高密度リポタンパク質コレステロール、低密度リポタンパク質コレステロール、サッカー

Abstract

The purpose of this study was to review the related literature to examine: 1) cross-sectional studies on serum lipids and lipoproteins in soccer players in the context of the potentially confounding factors such as dietary and nutritional intakes, obesity, cigarette smoking, alcohol intake, menstrual cycle, and playing positions in soccer, 2) acute effects of 90-min soccer match, and 3) effects of regular soccer training on lipid parameters in competitive and recreational soccer players. The most consistent observation regarding cross-sectional studies on lipid profile in soccer players is significantly higher high-density-lipoprotein cholesterol (HDL–C) than the controls. Research on the acute effects of 90-min of soccer match on the blood lipids and lipoproteins needs further attention, particularly it should correct plasma volume shifts. Participation in regular soccer training could decrease total cholesterol, triglycerides, low-density-lipoprotein cholesterol (LDL–C) and increase HDL–C in soccer players of different age groups. The most consistent observation regarding effects of recreational soccer training on lipid profile in both untrained men and women is significantly lowered LDL–C and/or LDL–C/HDL–C ratio. The changes in lipids and lipoproteins in soccer players could be caused by changes in activity levels of lipoprotein lipase, lecithin:cholesterol acyltransferase, and hepatic lipase. Future research investigating blood lipids and lipoproteins in soccer players should direct research towards the underlying mechanisms for changes in blood lipids and lipoproteins. These studies should, in particular, focus on women, adolescents and young adults since there is a paucity of information in the literature in this area.

Key words
lipids, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, soccer

1. Introduction

Good performance in soccer consists of many factors, including excellence in games skills, cognitive abilities to make correct decisions within the game, moderate to high aerobic and anaerobic power.[1–5] It is estimated that the total distance covered during a 90-min game amounts to about 10 km.[6, 7] Thus, running plays an essential role in soccer training and matches.[8] One study[9] investigated the effects of specific aerobic training, 4 times 4 min at 90–95 maximal heart rate (HRmax), with a 3 min jog between, twice per week for 8 weeks, on performance during soccer match and soccer specific tests. The results showed that enhanced aerobic endurance in soccer players improved soccer performance by increasing the distance covered, enhancing work intensity, and increasing the number of sprints and involvements with the ball during a match.

It has been reported that aerobic training increases high-density lipoproteins cholesterol (HDL–C) and decreases triglycerides (TG) and/or low-density lipoproteins cholesterol (LDL–C).[10–16] It has also been reported that active people in comparison with sedentary people tend to show lower total cholesterol (TC) and TG and/or higher HDL–C.[17, 18]

Many of the studies on the lipids and lipoproteins in athletes primarily examined their relative endurance activities,[19–23] whereas the lipids and lipoproteins in soccer players, whose training schedule consists of aerobic and anaerobic exercises, is less known.

Soccer is traditionally played as 11 against 11 players (11 vs 11), but it is also conducted as small-sided games, such as 3 vs 3, 4 vs 4, 5 vs 5, 9 vs 9.[24–29] The aerobic demands in recreational soccer are roughly similar to those in elite soccer training with periods of near HRmax values.[30–33]

The purpose of this study was to review the related literature to examine: 1) cross-sectional studies on serum lipids and lipoproteins in soccer players in the context of the potentially confounding factors such as dietary and nutritional intakes, obesity, cigarette smoking, alcohol intake, menstrual cycle, and playing positions in soccer, 2) acute effects of 90-min soccer match on serum lipids and lipoproteins, and 3) effects of regular soccer training on serum lipids and lipoproteins in competitive and recreational (small-sided game) soccer players. The potential mechanisms responsible for the changes in blood lipids and lipoproteins are also discussed.

2. Confounding Factors

Although positive effects of physical exercise on serum lipids and lipoproteins have been obtained in numerous studies, results from cross-sectional studies become equivocal when several confounding variables, such as body mass, body composition, dietary habits, lifestyle, alcohol intake, and smoking, are considered.[34] Thus, to evaluate blood lipids and lipoproteins in soccer players should provide sufficient control for the potential confounding effects of such variables.

2.1. Nutrition

An adequate carbohydrate intake is important in soccer because significant glycogen depletion has been observed after soccer matches.[35] Balsom et al.[36] reported that pre-game muscle glycogen concentrations following high carbohydrate diet were significantly higher than following low carbohydrate diet. Also, the players performed significantly higher (approximately 33%) intensity exercise in the game played following the high carbohydrate diet. Carbohydrate-electrolyte solution ingestion improves endurance capacity during intermittent high-intensity running.[37] Ali and Williams[38] reported that there was a 3% reduction in skill performance from before to after exercise in the 6.4% carbohydrate-electrolyte solution trial, whereas in the placebo trial the decrease was 14%. Individuals consuming a high-carbohydrate diet tend to show lower HDL-C than those who consume a low-carbohydrate diet.[39, 40] Japanese people have quite different dietary habits, which are characterized by a high carbohydrates intake, along with low protein and fat intakes,[41] than people living in Western countries. Regarding soccer players, it has been reported that the mean percentage of energy from carbohydrate for the Japanese players (62.7%)[42] was higher than Italian professional players (55.8%),[43] Puerto Rican Olympic players (53.2%),[44] elite Swedish players (47%),[35] Danish players (46.3%),[45] elite Spanish adolescent players (45%),[46] and professional Spanish female players (44.3%).[47] In addition to carbohydrate intake, saturated fatty acids, cholesterol, and excess caloric intake raise serum LDL-C,[48] Consumption of fruit and vegetables is inversely related to LDL-C.[49–51]

2.2. Obesity

Soccer players tend to show significantly lower percentage of body fat (%Fat) than the sedentary controls in male[43] and female.[52] A review article by Rico-Sanz[53] shows that the average %Fat of outfield players is about 10%. There appears to be little difference in %Fat among the different outfield positions, although midfielders tend to have lower %Fat. %Fat of professional goalkeepers is about 13%. Very few data is available for female players' %Fat, which is about 19%[52] to 21%.[53]

Lean subjects, in comparison with their counterparts, tend to show lower TC, TG, and LDL-C, and/or higher HDL-C.[54–57] It has been reported that %Fat showed a significant positive correlation with TG and a negative correlation with HDL-C after adjusting for age and maximal oxygen uptake ($\dot{V}O_2$-max).[58–60] It has also been reported that body mass index (BMI) was positively related to LDL-C and TG.[61, 62]

2.3. Cigarette smoking and Alcohol intake

Although smoking rate in soccer players

has not been reported, some studies stated that they excluded smokers.[63, 64] It has been reported that cigarette smoking was negatively associated with HDL–C and positively with TG, and smokers show significantly higher TG and lower HDL–C and/or HDL_2–C.[65–67] Smokers tend to have a higher alcohol intake than non-smokers, and cigarette smoking show a significant positive correlation with alcohol intake.[67, 68] It has been reported that alcohol consumption was positively associated with HDL, HDL_2, and/or HDL_3.[69, 70] Alcohol drinkers show a higher HDL–C than non-drinkers.[71–74]

2.4. Menstrual Cycle

Menstrual cycle can influence lipid metabolism. Estradiol increases TG and HDL_2–C.[75] Estradiol changes across the menstrual cycle, and an increase of HDL–C at ovulation in healthy women has been reported.[76, 77] These changes in estradiol and HDL–C have deterred many researchers from including women as study participants in order to avoid complications in sample collection procedures during experimental protocols.[78]

2.5. Playing Positions in Soccer

In soccer, differences in physiological demands exist among offensive, midfield, and defensive positions, based on a presumption of higher endurance demands on the more active midfield players,[2] who showed significantly higher $\dot{V}O_2max$ compared with defense players.[2, 79, 80] It has been reported that $\dot{V}O_2$-peak or $\dot{V}O_2max$ significantly increase after aerobic training.[81–85] Also, soccer specific endurance training increase $\dot{V}O_2max$.[9, 86] Aerobic training increases HDL–C and lowers TG and/or LDL–C.[10–16]

4. Serum Lipids and Lipoproteins in Soccer Players

4.1. Cross Sectional Studies in Men

Ruiz et al.[87] investigated plasma lipids profile of 28 swimmers, 17 volleyball players, 23 soccer players, and 26 sedentary controls. All sport players participated in official national competitions. All groups were matched according to age, BMI, and nutritional status. However, exercise regimens of swimming (continuous, aerobic component=95%, anaerobic component=5%), volleyball (high intensity and intermittent, aerobic component=60%, anaerobic component=40%), and soccer (high intensity and intermittent, aerobic component=70%, anaerobic component =30%) differ significantly. The results showed that the swimmers showed significantly lower TC than the volleyball players, and significantly lower LDL–C and apo B100 and higher HDL–C than the volleyball and soccer players. The swimmers also showed significantly higher apo A–Ⅰ than the other 3 groups. The soccer players showed significantly higher lipoprotein (a) than the other 3 groups. The results of this study showed that persons who practice sports involving a high level of physical exertion (volleyball and soccer players) had a less favorable lipid profile. In contrast, swimmers had a more favorable lipid profile. The authors concluded that stressful physical exertion can lead to abnormalities in plasma lipid profile.

Giada et al.[43] examined 20 professional soccer players and did not find any significant differences between the soccer players and the controls in terms of TC, TG, HDL–C, LDL–C, apolipoprotein (apo) A–Ⅰ, A–Ⅱ, B, C–Ⅱ, C–Ⅲ, and E. Although the soccer players showed significantly lower %Fat and alcohol intake and higher energy intake, there were no significant correlations between lipid parameters and anthropometric or dietary variables in multivariate analysis when the subjects were considered as a whole. Zanella et al.[88] also did not find any significant differences in lipid profiles (TC, HDL–C, LDL–C, VLDL–C, TG, and apo A–I) between 20 professional players and 20 controls.

Lehtonen and Viikari[89] examined 2 Finnish top class soccer teams; there were 21 players in team A and 16 players in team B. The team A had more aerobic exercise in their training program than the team B. Control group was consisted 61 healthy young men. There were no significant differences among 3 groups in relative body weight (weight/height − 100) and age. Also, results of dietary questionnaires suggested food and ethanol intake habits were essentially similar in all groups. The results showed that the players in the team A had significantly higher TC and HDL–C than the players in the team B and significantly higher HDL–C than the controls. There were no significant differences between the players in the team B and controls in lipid parameters. Tsopanakis et al.[90] compared lipid and lipoprotein profiles of 9 Olympic sports players. The authors stated that all athletes had a normal diet, were nonsmokers, and did not receive any special medication except certain vitamins (B, C, etc.); the controls were similar. All subjects consumed no or very little alcohol. The results showed that the soccer players had significantly higher HDL–C and lower LDL–C than the controls.

The above mentioned 2 studies[89, 90] showed that the soccer players had significantly higher HDL–C and/or lower LDL–C. However, they did not measure HDL–C subfractions.

Brites et al.[63] compared 30 male well trained soccer players and 12 sedentary controls. The soccer players engaged in a physical training program that consisted of 20 hours of training and 6 soccer matches per week for at least 1 year. Both groups showed similar age, BMI, and waist/hip ratio. The subjects were not taking any drug known to affect the lipid and lipoprotein metabolism. The subjects who were taking anabolic drugs, vitamins, or other antioxidants, or who were smokers were excluded from the study. Ethanol intake was considerably less than 50 g per week in all subjects. Dietary information was obtained with a food frequency questionnaire. The quality, quantity, and frequency of consumption of red meat, chicken, fish, eggs, vegetables, fruits, milk products, and soft drinks was similar in all subjects. The results showed that HDL–C and HDL_3–C concentrations were significantly higher in soccer players compared with those in sedentary controls. Another study by Brites et al.[64] compared 35 male well trained soccer players and 15 sedentary controls. The subjects were matched by age, BMI, and waist/hip ratio. Their training program, the subjects exclusion criteria, ethanol intake, and dietary habits were very similar to the previous study.[63] The results showed that HDL–C and HDL_2–C concentrations were significantly higher in soccer players compared with those in sedentary controls.

The above mentioned cross-sectional studies in soccer[43, 63, 64, 87–90] just compared soccer players as a whole to sedentary controls. Imamura et al.,[91] using 31 well trained male collegiate soccer players, divided into 2 groups:

16 defenders and 15 offenders. They were compared with 16 sedentary controls. The subjects were all non-smokers and were not taking any drug known to affect the lipid and lipoprotein metabolism. Dietary information was obtained with a food frequency questionnaire. There were no significant differences among 3 groups in BMI, alcohol consumption, and intakes of fat, cholesterol, saturated fatty acid, polyunsaturated fatty acid, polyunsaturated and saturated fatty acid ratio, yellow and green vegetables, other vegetables, and fruits. The results showed that the offenders had significantly higher HDL–C, HDL_2–C, and apo A–Ⅰ than the defenders and controls, whereas the defenders had the significantly higher HDL_2–C than the controls.

Although the results of the cross-sectional studies in men are controversial, the most consistent observation regarding lipid profile in soccer players is significantly higher HDL–C than the controls.[63, 64, 89–91] The higher HDL–C concentrations in soccer players could be attributed to higher HDL_2–C[64, 91] or HDL_3–C.[63]

The divergent results obtained in these studies could be due to the differences in training status, cardiorespiratory fitness levels, nutrient intake, and variations in the frequency, duration, and intensity of training (aerobic and anaerobic components), and/or other confounding factors as mentioned previously.

4.2. Cross Sectional Studies in Women

Nishimura et al.[52] compared competitive female collegiate soccer players with age, body height and weight-matched controls. The subjects were all non-smokers and consumed very little alcohol. The results showed that the soccer players had significantly higher serum HDL–C than the controls. This study, however, did not measure HDL–C subfractions. Also, the soccer players showed significantly higher energy, carbohydrate, protein, and raw meat intakes. Furthermore, menstrual cycle periodicity was not examined in this study.

Research on the blood lipids and lipoproteins in female soccer players needs further attention, particularly it should provide sufficient control for the potential confounding effects of factors as mentioned previously.

4.3. Acute Efffects of 90-Min of Soccer Match on Blood Lipids and Lipoproteins

Rahnama et al.[92] investigated the impact of a 90-min match on lipid parameters of 22 professional soccer players. Lipid parameters were measured at rest and immediately after a 90-min soccer match. The results showed that TG significantly decreased and LDL significantly increased in comparison with resting values. Sotiropoulos et al.,[93] on the other hand, examined lipids changes after a soccer match in male amateur players whose habitual training regiment consisted of 4–5 times a week for about 75–90 min per training session. Also, to avoid any confounding effects of individualized nutrition, subjects followed a balanced diet containing 55% carbohydrates, 15% protein and 30% lipid (average daily energy intake: 2,784±150 kcal) for six weeks before the study. These authors reported that HDL and apo A increased significantly, while TC, LDL, apo B, TG, LDL/HDL ratio, TC/HDL ratio apo A/apo B ratio decreased significantly. It is concluded that intermittent soccer match results in an acute antiatherogenic modification of lipid profile, possibly due to the high aerobic energy expenditure.

The divergent results obtained in the above mentioned 2 studies[92, 93] could be due to the differences in training status (professional vs. amateur players), cardiorespiratory fitness levels, nutrient intake, and variations in the frequency, duration, and intensity of training (aerobic and anaerobic components). In addition, these studies did not correct plasma volume shifts. When blood lipids and lipoproteins are measured immediately after soccer match, a change in plasma volume may possibly result in an artificial inverse change in the measured lipid parameters. Plasma volume decreases during dehydration,[94] which are influenced by duration and intensity of exercise and environmental conditions.[95] It has been shown that sweat losses during soccer training in cool environments were 1.69±0.45 L (5 degrees C, 81% relative humidity)[96] and 1.68±0.40 L (6–8 degrees C, 50–60% relative humidity),[97] in warm environment (24–29 degrees C, 46–64% relative humidity) was 2.03±0.41 L,[98] and in hot environments were 2.19±0.37 L (32±3 degrees C, 20±5% relative humidity)[99] and 3.1 ±0.6 L (34.3±0.6 degrees C, 64±2% relative humidity).[100]

Bloomer and Farney[101] examined 3 different bouts of acute exercise of varying intensity and/or duration and reported that plasma volume decreased significantly for all exercise bouts, with the greatest decrease noted 0 min post-exercise for sprint bouts (~19%) compared with aerobic exercise bouts (~11%). As examined above, research on the 90-min of soccer match on the blood lipids and lipoproteins needs further attention, and future research should include the use of appropriate correction equations (e.g. Dill & Costill, 1974)[102] for potential plasma volume shifts.

4.4 Effects of Soccer Training

4.4.1. Elite Soccer Players

Manna et al.[103] investigated the effect of training on physiological and biochemical variable of Indian male soccer players of different age groups. The players were equally divided (n=30) into 4 groups: under 16 years (U16y); under 19 years (U19y); under 23 years (U23y); and senior. These subjects were selected from the training camps at Sports Authority of India. The training sessions were divided into 2 phases: preparatory phase for 8 weeks and competitive phase for 4 weeks. The training program consisted of aerobic, anaerobic and skill development, and were completed 4 hours/day; 5 days/week. The measurements were taken at baseline and at the end of preparatory phase and competitive phase. The results showed that, in comparison with baseline, HDL–C increased significantly among the players of U16y at the end of preparatory phase and competitive phase. TC decreased significantly among the players of U23y at the end of preparatory phase and among the players of U19y and U23y at the end of competitive phase. TG decreased significantly among the players of U23y at the end of preparatory phase and among the players of U23y and senior at the end of competitive phase. LDL–C decreased significantly among the players of U19y at the end of preparatory phase and competitive phase. These results indicate that participation in regular soccer training could decrease TC, TG LDL–C and increase HDL–C in soccer players of different age groups.

4.4.2. Recreational Soccer

Krustrup et al.[104] examined the effects of regular participation in recreational soccer in 36 healthy untrained Danish men aged 20–43 years. They were randomised into a soccer group (n=13), a running group (n=12) and a control group (n=11). Training was performed for 1 hour, 2 or 3 times per week for 12 weeks; at an average heart rate of 82% of HRmax. During the 12 week period, $\dot{V}O_2max$ increased significantly by 13% and 8% in soccer and running groups, respectively. After the 12 weeks of training, fat mass was 3.0% and 1.8% lower for soccer and running groups, respectively. Only soccer group had an increase in lean body mass (1.7 kg) and a decrease in LDL–C (2.7 to 2.3 mmol/l). TC and HDL–C did not change significantly. No changes in any of the measured variables were observed for controls. These results indicate that participation in regular recreational soccer training, organized as small-sided drills, has significant beneficial effects on physical capacity and LDL–C for untrained men, and in some aspects it is superior to frequent moderate-intensity running.

Randers et al.[105] examined the effect of 12 weeks of small-sided street soccer (2.2 sessions/week) and fitness center training (0.5 sessions/week) on physical fitness and cardiovascular health profile for homeless men. Blood lipid profile was determined before and after the intervention period for 22 soccer players and 10 controls. During a 60 min 4 versus 4 street soccer session, mean HR was 82% HRmax and HR was greater than 90% HRmax for 21% of total time. In soccer group, $\dot{V}O_2max$ was significantly elevated from 36.7 to 40.6 ml/min/kg after 12 weeks and incremental cycle test performance was significantly improved by 81 seconds. After 12 weeks, %Fat (19.4 to 17.5%) and LDL–C (3.2 to 2.8 mmol/l) were significantly lowered in soccer group. The observed changes in soccer group were significantly different from the controls and no intra-group changes occurred for controls. These results indicate that the exercise intensity is high during street soccer, and regular street soccer training has significant beneficial effects on physical fitness and LDL–C for homeless men.

Krustrup et al.[106] examined the cardiovascular health effects of 16 weeks of recreational soccer training in untrained premenopausal women in comparison with continuous running training. Fifty healthy women were matched and randomized to a soccer (n=25) or a running (n=25) group and compared with a control group (n=15). Training was performed for 1 hour twice a week. After 16 weeks, $\dot{V}O_2max$ was significantly elevated by 15% in soccer group and by 10% in running group. Total fat mass significantly decreased by 1.4 kg in soccer group and by 1.1 kg in running group. Although TC, HDL–C, and LDL–C did not change significantly, LDL–C/HDL–C ratio was significantly lowered in soccer group, but not altered in running group. No changes were observed in controls. These results indicate that participation in regular recreational soccer training has significant beneficial effects on physical capacity and LDL–C/HDL–C ratio for untrained premenopausal women, and is at the least as efficient as continuous running.

The most consistent observation regarding effects of recreational soccer training on lipid profile in both untrained men and women is significantly lowered LDL–C and/or LDL–C/HDL–C ratio.

5. Potential Mechanisms

There are several possible mechanisms that could explain how soccer training and match changes blood lipids and lipoproteins in soccer players. They could be caused by changes in activity levels of several lipid-regulatory enzymes, which are lipoprotein lipase (LPL), lecithin:cholesterol acyltransferase (LCAT), and/or hepatic lipase.

5.1. Lipoprotein Lipase

LPL hydrolyzes both chylomicron and VLDL on the vascular endothelium and generates precursor of HDL during lipolysis of TG-rich lipoproteins.[107] Thus, increase in this enzyme activity may increase HDL–C and decrease TG. Kantor et al.,[108] using 10 well-trained men, reported that LPL activity was nearly doubled after participating in a marathon and suggested that increase in LPL activity probably mediated the increase in HDL–C. Kiens and Richter[109] investigated prolonged bicycle ergometer exercise to exhaustion in 8 healthy young men and reported that muscle LPL activity significantly increased by 72% compared with values before exercise. Herd et al.,[110] on the other hand, examined 8 physically active men who cycled for 90 min at 62.3% of VO_2max. The results showed that muscle LPL activity did not change significantly after exercise. Harrison et al.[111] also reported that muscle LPL activity did not change significantly in 8 moderately active men who cycled for 90 min at 70% $\dot{V}O_2$peak followed by ten 1 min full effort sprints interspersed with 1 min of resting recovery.

5.2. Lecithin:cholesterol Acyltransferase activity

LCAT esterifies cholesterol on HDL, which is enriched with cholesteryl ester and become larger, resulting in HDL_3–C and HDL_2–C.[112] Thus, increase in this enzyme activity may increase HDL–C. Gupta et al.[113] found increased LCAT activity in endurance athletes compared with that in controls. Imamura et al.[114] also found increased LCAT activity in rugby players. Frey et al.[115] found increased LCAT activity after a maximal aerobic stress test in both endurance-trained and sedentary groups. Williams et al.[116] reported that a one-year running program did not significantly affect mean LCAT-mass concentrations. Wallace et al.[117] investigated the acute effects of high- and low-volume resistance exercise sessions and found that LCAT activity was significantly depressed 24 h post-exercise following the high-volume session.

Regarding soccer players, the above mentioned study by Imamura et al.,[91] reported that both offenders and defenders had significantly higher LCAT activity than the controls. Brites et al.,[64] on the other hand, did not find any significant difference between the soccer players and the controls in LCAT activity although the capacity to promote cholesterol efflux was significantly higher in the soccer players than in the controls. The divergent results obtained in these studies could be due to the differences in training status, cardiorespiratory fitness levels, nutrient intake, and variations in the frequency, duration, and intensity of training.

5.3. Hepatic lipase activity

Hepatic lipase converts the large, TG-rich HDL_2, back into small TG- and cholesteryl ester-poor HDL_3–C.[112] Thus, a decrease in hepatic lipase activity could cause an increase in HDL–C. However, hepatic lipase activity has never been investigated in soccer players.

The underlying physiological mechanisms for changes in lipids and lipoproteins remain inconclusive. More research is needed to examine mechanisms that could explain how soccer training changes blood lipids and lipoproteins.

6. Directions for Future Research

Future research investigating the lipid profile of soccer players should examine: 1) differences between playing positions: defenders and offenders, 2) acute effects of 90-min of soccer match with correction of plasma volume shifts, and 3) chronic effects of highly skilled and recreational soccer training, directing research towards the underlying mechanisms for changes in blood lipids and lipoproteins. These studies should, in particular, focus on women, adolescents and young adults since there is a paucity of information in the literature in this area.

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