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Interaction Between Alcohol and Exercise

Physiological and Haematological Implications

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Abstract

Alcohol use, particularly excessive alcohol consumption is one of the most serious health risks in the world. A relationship between sport, exercise and alcohol consumption is clear and long-standing. Alcohol continues to be the most frequently consumed drug among athletes and habitual exercisers and alcohol-related problems appear to be more common in these individuals. Alcohol use is directly linked to the rate of injury sustained in sport events and appears to evoke detrimental effects on exercise performance capacity. The model of alcohol consumption in human experimental studies has either been acute (single dose) or chronic (repeated doses over a period). These studies suggested that alcohol consumption decreases the use of glucose and amino acids by skeletal muscles, adversely affects energy supply and impairs the metabolic process during exercise. In addition, chronic alcohol use is associated with increased citrate synthase activity and decreased cross-sectional area of type I, IIa and IIb fibres. There is evidence to suggest that exercise may attenuate the ethanol-induced decline in hepatic mitochondria and accelerates ethanol metabolism by the liver. Exercise training seems to reduce the extent of the oxidative damage caused by ethanol. Evidence generated from *in vitro* experiments and animal studies have also

suggested that ethanol administration decreased skeletal muscle capillarity and increased pyruvate kinase and lactate dehydrogenase activities. Substantial epidemiological evidence has been accrued showing that moderate ingestion of alcohol may reduce the incidence of cardiovascular diseases. Although the existing evidence is often confusing and disparate, one of the mechanisms by which alcohol may reduce the incidence of mortality of cardiovascular diseases is through raising levels of high-density lipoprotein cholesterol. Available evidence suggests that exercise and moderate alcohol consumption may have favourable effects on blood coagulation and fibrinolysis; however, compelling experimental evidence is lacking to endorse this notion. Occasional and chronic alcohol consumption is usually linked with unfavourable alterations in platelet aggregation and function and may be associated with platelet-related thrombus formation. Although the effects of alcohol consumption on the rheological properties of the blood are not known, recent experimental evidence suggests that alcohol use following exercise is associated with unfavourable changes in the main determinants of blood viscosity. It is well documented that alcohol use modulates the immune system and impairs host defence. Compelling evidence is also mounting to suggest that chronic alcohol use is linked with adverse effects on the body systems and organs including the brain, the cardiovascular system and the liver.

1. Alcohol Consumption in Sports and Exercise

Alcohol abuse ranks among the most common and severe environmental hazards to human health. Alcohol consumption is part of the social aspects of many sporting events and is the most widely used drug among sport participants and athletes. Alcohol use is one of the biggest drug problems in the Western world and its misuse is deeply intertwined into exercise and sport activities. Alcohol consumption is by far the cause of the most serious and insidious drug problems on college and university campuses. Alcohol is a dependence-producing drug and this dependence is associated with an increased rate of morbidity and mortality from different diseases. Alcohol is a drug and its use affects different bodily systems and interferes with varying medical conditions. The link between alcohol consumption and sport extends from ancient times when alcohol was considered the elixir of life.[1] Alcohol use is directly linked to the rate of injury sustained in sport events and appears to evoke detrimental effects on exercise performance capacity. The epidemiological evidence available[2] suggests that the pattern of alcohol consumption varies among different sports. The highest percentage of athletes who consume alcoholic beverages was found in sports such as rugby, cricket, hurling, soccer and Gaelic football compared with sports such as horse racing, cycling and tennis. However, the amount of alcohol used by athletes during training was low,[3] with an average weekly intake in athletes engaged in different sports below the recommended level advised by the World Health Organization and the Royal College of Physicians.[4]

It remains a common belief among habitual exercisers that the consumption of small amounts of alcohol improves athletic performance. In order to provide a foundation regarding alcohol use in sports and exercise, the American College of Sports Medicine concluded in a Position Stand[5] the following guidelines on the effects of alcohol consumption on exercise performance:

- psychomotor skills are adversely affected by acute alcohol consumption;
- maximal aerobic power as assessed by maximal oxygen consumption ($\dot{V}O_{2max}$) is minimally influenced with acute alcohol consumption;

- acute alcohol ingestion is not associated with improvement in exercise capacity and may decrease the performance level;
- the consumption of alcohol may perturb the body's temperature regulation mechanisms during exercise particularly in a cold environment.

Exercise and training specialists should understand and be instructed about the possible harmful effects and the limitations of alcohol use in exercise and sports. Fitness trainers and coaches, and physical therapists have obligations to follow the above guidelines and be educated in these areas.

2. Alcohol Use and Exercise Training: Effects on Skeletal Muscle

The effects of alcohol on the body systems are complex and the problems associated with its excessive and frequent use are numerous. Alcohol affects several bodily organs either directly or indirectly through the metabolites formed during its biological transformation.[6] Initiatives to identify metabolic pathways through which alcohol consumption impairs muscle functions has substantially increased in recent years. For example, it has been unequivocally shown that alcohol consumption decreases the use of glucose and amino acids by skeletal muscles with adverse effects on energy supply and impairment in the metabolic process during exercise.[7-16] Previous studies have shown that alcoholic myopathy is usually described in glycolytic muscles, in which protein turnover and glucose metabolism deficiencies are associated with chronic alcohol consumption.[7] Other studies have indicated that exercise may attenuate the ethanol-induced decline in hepatic mitochondria and that exercise performance accelerates ethanol metabolism by hepatic microsomes.[8,9] In an animal model, Husian and Somani[10,11] showed that exercise training seems to reduce the extent of the oxidative damage caused by ethanol on the liver, myocardium and testes.

Vila et al.[12] examined the effects of aerobic exercise on the skeletal muscle metabolism, capillary density and distribution, myofibrillar distribution and fibre morphology of ethanol-treated rats. Ethanol administration decreased skeletal muscle capillarity and increased pyruvate kinase and lactate dehydrogenase activities. In addition, chronic alcohol administration was associated with increased citrate synthase activity and decreased cross-sectional area of type I, IIa and IIb fibres. Interestingly, the decreased capillarity induced by the administration of alcohol in some skeletal muscles was ameliorated when alcohol consumption was combined with exercise training. It was concluded that exercise training could decrease some of the harmful effects produced by ethanol in the muscle. Available evidence also suggests that the extensor digitorum longus and soleus muscles of chronic alcohol-treated rats exhibit marked changes in glucose metabolism, particularly glycogen synthesis.[13] This was attributed to a reduction of glucose uptake by 50% in rat skeletal muscle, particularly in hyperinsulinaemic animals in which basal glucose level is doubled.[14] A further study was conducted because of the significance of metabolic enzymes and the possible effects of alcohol on these enzymes during the process of energy production and protein synthesis in the skeletal muscle.[15] The results showed a reduction in metabolic enzyme activities of the vastus lateralis muscle in rats that were exposed to chronic alcohol consumption.

It is commonly accepted that the number of capillaries surrounding the individual muscle fibre is related to its oxidative capacity. It is also known that endurance training increases capillary distribution in exercising muscle to allow a greater surface area for the exchange of gases, metabolites and metabolic substrates.[16] Although information on the influence of alcohol on the skeletal muscle capillary density and distribution is limited, it has been shown that acute alcohol use is associated with tissue vasodilatation in the periphery.[17] In contrast, chronic alcohol consumption is associated with diminished vascular lumen, which may be responsible for the development and progression of alcoholic myopathy.[18] In addition, the results of the same study[18] showed a decreased skeletal muscle capillarity in alcoholic myopathy. There are also reports[9] showing a decrease in capillary density with chronic alcohol ingestion, but this unfavourable effect ap-

pears to be attenuated by exercise. Interestingly, exercise overturned the damage caused by alcohol in the skeletal muscles, particularly those muscles with a higher percentage of type IIb fibres, such as white gastrocnemius muscle. Underlying mechanisms for these effects are not obvious.

The possible influence of alcohol on muscle fibre type and muscle protein content was examined in the rat. For example, Preedy et al.[19] showed that the ingestion of alcohol was associated with a decrease in skeletal muscle weight with a concomitant reduction in DNA and RNA content, primarily in type II fibres. The reasons how alcohol consumption induces such alterations were examined in earlier reports.[19] The results showed that alcohol-related muscular atrophy was due to alterations of the glycolytic metabolism and neurogenic damage.[20] It should be noted that these studies are almost all performed on animals in a laboratory setting. Although this enables accurate analysis and data collection, it may not necessarily reflect the effects of alcohol consumption on the physical, physiological and histochemical characteristics of the skeletal muscle in humans.

3. Haematological Profiles and Alcohol Use in Exercise and Training

3.1 Blood Coagulation and Fibrinolysis

Although epidemiological data suggest that exercise and moderate alcohol consumption may have favourable effects on blood coagulation and fibrinolysis, compelling experimental evidence is lacking to endorse this notion. It is documented that acute exercise is usually associated with various degrees of hyper-coagulability, which is counterbalanced by a corresponding activation of blood fibrinolysis.[21] During the last decade, substantial epidemiological evidence has been accrued showing that moderate ingestion of alcohol reduces the incidence of coronary heart disease. However, the existing evidence is often confusing and disparate. Some of the mechanisms by which alcohol may reduce the incidence of mortality of coronary heart disease is through raising high-density lipoprotein-cholesterol, reduced platelet aggregability, and also favourable alterations in blood coagulation and fibrinolysis.[22] The reversed relationship between chronic alcohol consumption and plasma fibrinogen concentration has also been implicated as a possible pathway for reduced cardiac thrombosis.[23] In addition, elevated levels of tissue-plasminogen activator (t-PA) antigen associated with regular alcohol consumption may represent a beneficial physiological response to combat thrombotic risks.[24] However, in epidemiological studies it is usually difficult to distinguish the effects of alcohol from those of diet, tobacco, drugs and socioeconomic influences. In contrast to these epidemiological results, blood haemostasis is unfavourably influenced by the acute ingestion of alcohol in young[25] and middle-aged individuals.[26] The mechanisms underlying alcohol-related thrombotic events are so far unclear.

Although epidemiological studies have demonstrated a positive correlation between alcohol consumption and blood fibrinolytic activity,[27] experimental data on the effects of alcohol use on blood coagulation and fibrinolysis are few and controversial. For example, Hendriks et al.[28] investigated the short-term effects of moderate consumption of beer, wine and spirits on blood fibrinolysis in middle-aged men. The results showed a marked increase in plasminogen activator inhibitor-1 (PAI-1) activity and antigen, whereas t-PA was significantly decreased. Pikaar et al.[29] studied the long-term effects of consuming varying doses of red wine on selected blood haemostatic indices. Although t-PA activity showed a large and dose-dependent decrease (hypofibrinolysis), plasma fibrinogen concentration did not change significantly with red wine consumption. In a recent study, the acute effects of ingesting a large dose of alcohol on the haemostatic system and its circadian pattern was examined in 12 healthy, non-smoking men.[30] The results indicated that acute ingestion of a relatively large, but tolerable dose of alcohol lead to a substantial increase in PAI-1 activity and a small rise of urinary excretion of thromboxane β_2 (2,3-dinor-TXβ_2). These effects were independent of the circadian variation of the haemostatic system and may promote thrombogene-

sis; particularly when alcohol is consumed in large amounts before going to bed in the evening. These results contrast with data of other reports[31,32] in which alcohol use had no demonstrable effects on blood coagulation and fibrinolysis.

The implications of alcohol use on other haematological profiles in sport and exercise have not been systematically investigated, although cumulative evidence continues to suggest that alcohol consumption, in general, is detrimental or unbeneficial to sport and exercise performance. It is intriguing, however, that athletes continue to consume alcohol on a chronic basis and even immediately prior to sports events.[33] The effects of moderate alcohol consumption before exercise on blood coagulation and fibrinolysis was recently examined in a laboratory-controlled setting by El-Sayed et al.[34] Although no significant differences between alcohol and control trials were found, a significant decrease in fibrinogen concentration was observed after exercise only in the alcohol trial. The majority of previous studies on the interrelationship between alcohol consumption, exercise and fibrinogen were epidemiological in nature and the mechanism responsible for the decrease in fibrinogen following exercise noted by El-Sayed et al.,[34] might be related to inhibition of fibrinogen synthesis by the liver or an enhanced rate of its catabolism. Data from the same laboratory[35] indicated that moderate alcohol ingestion prior to exercise significantly decreased exercise-induced hyperfibrinogenolysis. It is probable that alcohol ingestion inhibited fibrinogen catabolism and/or enhanced the removal of its degradation products from the circulation. The potential importance of this observation warrants further study, both to elucidate the clinical significance of alcohol effects on exercise-induced hyperfibrinogenolysis and to determine its mechanism of action.

The possible effects of low (0.4g ethanol/kg bodyweight) and high (0.8g ethanol/kg bodyweight) concentrations of red wine consumption at night on indices pertinent to the fibrinolytic enzyme system were examined the subsequent morning at rest and following exhaustive exercise (outdoor running for 20 minutes) in young, healthy, non-smoking and physically active subjects.[36] Results showed that red wine consumption decreased blood fibrinolysis at rest as reflected by a dose-related increase in PAI-1 antigen levels, but not in t-PA antigen. This occurred in parallel with prolongation in whole blood clot lysis time (WBCLT). Following exercise, PAI-1 and t-PA increased significantly with concomitant prolongation of WBCLT and the consumption of red wine the night before had a favourable effect on exercise-induced hyperfibrinolysis.

It is known that exercise induces modifications in blood haemostasis. It is, however, not known whether alcohol consumption post-exercise influences these modifications. Recent evidence has suggested that alcohol consumption (0.7 g/kg body mass) after exercise perturbs blood haemostasis during recovery. Factor VIII (FVIII) was amplified significantly at 5 and 22 hours during recovery when subjects ingested a moderate amount of alcohol following exercise.[37] These findings are similar to those of Hillbom et al.[38] who administered a higher dose of alcohol (1.5 g/kg body mass) and found an increase in FVIII 1–3 hours after alcohol ingestion with the highest increase being observed 16 hours after alcohol consumption. The mechanism underlying the alcohol-induced increase in FVIII might be related to hormonal changes, such as an increase in vasopressin[39] and/or an increase in sympathetic nervous activity and catecholamines release.[40] Both catecholamines and vasopressin can induce an increase in FVIII. The increase in FVIII, together with some conventional risk factors such as age, smoking and abnormal lipid profiles, has been implicated in the atherosclerosis process in prospective studies.[41]

Alcohol ingested post-exercise lead to an inhibitory effect on fibrinolytic activity as reflected by an increase in PAI-1 antigen at 22 hours during recovery.[37] These results are in agreement with earlier observations when a single dose of alcohol was consumed. For example, total PAI-1 antigen and activity were significantly increased on the next day[32] and 2, 3, 5 and 9 hours after the ingestion of a moderate dose of alcohol. The mechanism responsible for alcohol-related changes in PAI-1 is unclear, but it may be related to the influence of acetaldehyde

(the main metabolite of alcohol) in the release of PAI-1 from the endothelium. Unlike PAI-1 activity and antigen, t-PA activity was significantly decreased in response to alcohol ingestion.[42] Elevated antigenic levels of t-PA and PAI-1 22 hours after the ingestion of alcohol following exercise could partly support the hypothesis put forward by Hendriks et al.,[42] that alcohol stimulates the secretion of t-PA and PAI-1 from endothelial cells. Although recent studies have shown that reduced fibrinolytic activity, largely due to elevated PAI-1 activity, can constitute a thrombotic risk factor in atherosclerosis,[43] the adverse impact of the transiently increased PAI-1 activity in response to alcohol ingestion remains to be established.

3.2 Platelet Aggregation and Function

Platelet aggregation is a complex process that is affected by a multitude of internal and external factors. Clinical and pathological studies have indicated that impaired platelet function is linked with the pathogenesis and progression of cardiovascular disease.[44] Although exercise effects on platelet aggregation and function have been previously examined and recently reviewed, the results reported have been conflicting.[45] It is common for sport participants to drink alcohol immediately following competition and training. A few case-controlled studies showed that alcohol drinking, particularly drinking to produce intoxication, might trigger the onset of brain infarction.[25,38,46] The pathological mechanism responsible for these events is not completely understood, although recent studies indicated unfavourable alterations in platelet aggregation and function with alcohol ingestion.[29] Acute drinking of a large amount of alcohol is associated with a transient, dose-dependent, increase in heart rate and blood flow. These haemodynamic changes (increase sheer) have been suggested as one of the pathways responsible for increased platelet aggregation and activation with alcohol drinking. Alcohol-associated sudden increase in sheer may not be dangerous if the blood vessels are not atheromatous, but may disturb the delicate *in vivo* balance between thromboxane and prostacyclin at the sites of severe atherosclerosis.[30]

Alcohol consumption accounts for 4–6% of the total energy intake and plays an important role in the diet in most Western countries.[3,47] However the exact effects of alcohol ingestion on platelet-related thrombus formation is not known. In recent years, considerable advances have been made to our understanding of the relationship between alcohol intake, lipoprotein metabolism and atherogenesis. Alcohol consumption is part of the social aspect of many sporting events and is the most widely used drug among sports participants and athletes, irrespective of their sex.[3] A worrisome aspect of alcohol ingestion is a temporary weakening of the left ventricular contraction and myocardial irritability, which may result in arrhythmia.[3] A few case-control studies showed that alcohol drinking, particularly drinking to produce intoxication may trigger the onset of brain infarction in young individuals.[46] The pathological mechanisms underlying these events are still unknown, although recent studies indicated unfavourable alterations in platelet aggregation and function with alcohol ingestion.[29]

El-Sayed[48] designed a laboratory-based study to examine the possible changes of platelet aggregation and activation when alcohol was ingested following exercise. Blood alcohol level increased significantly 1 hour after the ingestion of alcohol (mean ± SD; from 5.3 ± 1.9 mg/dL at rest to 59.6 ± 6.3 mg/dL 1 hour after ingestion). This rise in blood alcohol level returned to the resting baseline level at 5 hours post-exercise with no further changes until 22 hours during recovery. There was a marked increase ($p < 0.01$) in platelet count immediately after exercise and this occurred similarly in males and females. Platelet aggregation after induction with two different concentrations of adenosine diphosphate (ADP) was clearly decreased following exercise and during recovery when exercise was followed by the ingestion of a moderate dose of alcohol. Although the increase in platelet number post-exercise normalised 1 hour during recovery, platelet aggregation stimulated by *ex vivo* ADP exhibited a delayed return to the resting level during recovery only in the alcohol

trial. Platelet aggregation stimulated with the *in vitro* addition of collagen was not affected by exercise or alcohol ingestion. The resting level of β-thromboglobulin was within the normal level specified by the manufacturer of the reagent kit used. Although β-thromboglobulin levels following exercise increased by 26% for males and females (from a mean pre-exercise value of 22.3 to 28.1 IU/mL), this rise did not reach the designated level of significance ($p > 0.05$).[48] It was concluded that the ingestion of a moderate dose of alcohol following exercise perturbs and delays the normal recovery of platelet aggregation to the baseline level.

3.3 Blood Lipid Profiles

A perturbed blood lipid profile in coronary heart disease has been the focus of several clinical and epidemiological studies.[49] The effect exercise on blood lipid profiles have been extensively studied[50,51] and reviewed.[52,53] Although alcohol consumption could be associated with many health hazards,[54] it has been widely consumed through the ages because of its perceived benefits as a social lubricant and relaxation, and for mood alteration and sensory pleasure.[3] It is not uncommon for athletes and habitual exercisers to consume alcohol following exercise as a means of combating stress and relaxation. Although few studies are available on alcohol intake in relation to blood lipid profiles, varying results have been reported.[55-59] In addition, the effects of alcohol ingestion on blood lipid variables following situations where the sympathoadrenal system had been activated, as it is the case in exercise, are lacking. Information regarding lipid changes post-exercise, particularly when exercise performance is followed by the consumption of alcoholic beverages would be of clinical as well as scientific significance. El-Sayed and AL-Bayatti.[60] determined the effect of alcohol ingestion post-exercise on post-prandial lipaemia during recovery. Alcohol was given post-exercise to mimic the situation in real life. The mean values were compared with those obtained in a controlled experiment during which no alcohol was given. Nineteen normolipidaemic (11 males and 8 females) performed two exercise trials at an intensity corresponding to 70% $\dot{V}O_{2max}$ for 35 minutes. In a random order, alcoholic (0.7 g/kg) or alcoholic-free drinks were given 1 hour after the completion of exercise. Venous blood samples were obtained pre- (before breakfast) and post-exercise and pre- and post-prandially (lunch) during recovery. Total cholesterol and high-density lipoprotein-cholesterol showed no change to exercise or alcohol ingestion. In the controlled trial, when subjects consumed a standardised lunch there was no significant change in triglyceride levels, but when alcohol was consumed post-exercise, triglyceride levels increased substantially 5 hours during recovery in both males and females.

The mechanism responsible for the rise in triglyceride levels during recovery when alcohol was ingested following exercise is not known. Whether alcohol ingestion post-exercise retards triglycerides catabolism or augments its release by the liver and intestines remains unclear. It is possible that the increase in triglycerides in the alcohol experiment may have occurred as a consequence of an impaired removal of triglyceride-rich particles from the blood[55] or to an acute toxic effect of alcohol on the liver with a resultant inhibitory effect on lipoprotein lipase.[55,56] Probably by releasing adrenaline (epinephrine), alcohol increases free fatty acids mobilisation from adipose tissues, making them available to the liver for triglycerides formation.[61] The peak rise in triglycerides concentration occurred after the consumption of a standardised light lunch (5 hours following exercise). This finding may suggest that the effects of alcohol on triglycerides is dependent on the time of measurement and this may partly explain the diversity in reported results on the effects of alcohol on lipid profiles. Although a high level of circulating triglycerides is known to play an important role in the development of atherosclerosis,[49] the available evidence does not suggest that moderate alcohol consumption increases the risk of cardiovascular diseases.[62]

3.4 Blood Rheology

The effects of exercise on blood rheological characteristics have not received much research atten-

tion. Recent limited evidence suggests that different exercise protocols are usually associated with an increase in whole blood viscosity and plasma viscosity.[63] In a recent study, the effect of alcohol ingestion following exercise on blood rheology was examined in normal subjects.[64] Although whole blood viscosity was not measured in this study, its major determinants (plasma viscosity, plasma fibrinogen and haematocrit) were significantly increased following exercise. The consumption of alcohol after exercise delayed the normal return of plasma viscosity and plasma fibrinogen concentration to the resting level.[64] Although the mechanism responsible for these findings is not as yet known, it might be linked with alcohol-induced dehydration. The possible role of alcohol on blood rheology is inadequately established and further studies are warranted to unravel the exact effects of alcohol consumption on exercise-induced changes in blood rheology. These studies will guide a cornucopia of new research in the interaction between alcohol use and exercise in health and disease.

3.5 Alcohol Use and the Immune System

Alcohol use modulates the immune system and impairs host defence.[65] Increasing evidence from human and animal studies *in vivo* and *in vitro* indicated that alcohol can modulate the immune system at the level of innate and acquired immune responses. Alcoholics are more susceptible to infection with different pathogens and their ability to fight infection is impaired.[66] Recent evidence suggests that acute moderate alcohol consumption may also be associated with immunomodulatory effects.[67] Previous studies have indicated that lymphocytes and lymphocyte subpopulations in chronic alcoholics have consistently exhibited decreased lymphocytic cell numbers in the blood. Furthermore, chronic alcoholics are usually thought of as 'immunocompromised hosts' because of the increased incidence and severity of infections. Although the pathway responsible for the alcohol-induced decrease in lymphoid cell number is yet to be defined, apoptosis (programmed cell death) was proposed as the biological mechanism responsible for this effect.[68] Altered inflammatory neutrophil, leukocyte and microphage functions following acute and chronic alcohol use compromise the body's immune defence against infections. Furthermore, the humoral and cellular components of the immune system are also adversely affected by alcohol consumption. Impaired B lymphocyte functions and increased levels of certain types of immunoglobulins at the expense of others, disturb the delicate balance of the immune defence.[65,69,70] Recent evidence suggests that alcohol consumption is associated with impaired macrophage phagocytic functions and abnormal neutrophil leukocyte adherence and chemotaxis. These effects are likely to contribute to diminished local immune defence capacity and enhanced susceptibility to infections from bacterial and viral pathogens.[70] The generation of active oxygen radicals as a consequence of oxidative burst represents an important step in microbial death. Alcohol consumption adversely affects the production of the oxygen radicals, superoxide anion and hydrogen peroxide and this could play a pivotal role in antibacterial immune defence.[71,72]

4. Alcohol Use and Bodily Organs and Systems

It is universally accepted that alcohol consumption is one of the most serious health risks worldwide. Alcohol use is usually associated with pathological effects on different bodily organs and systems and can exacerbate a variety of medical anomalies. The link between alcohol use and the brain and the heart are the most extensively studied and the following discussion is designed to briefly review this area of study.

4.1 Alcohol Use and the Brain

The association between alcohol use and the risk of developing alcohol-related brain diseases is well documented. Earlier epidemiological studies suggested an association between brain damage; particularly stroke mortality and alcohol consumption.[73] For example, in a follow-up study for 13 years, Doll et al.[74] found a positive relationship between the adjusted death rates from stroke and the amount of

alcohol consumed among British male doctors. Although a decrease in the risk of death of ischaemic brain infarction was found in Swedish women who consumed <6 g/day alcohol[75] or <11 g/day alcohol in Australian women[76] compared with non-alcohol drinkers, no such effect was found in men. In a recent epidemiological follow-up study for 21 years on 600 Scottish subjects, results indicated a slight decrease in stroke mortality among individuals who consumed 1–7 units of alcohol per week.[77] However, the consumption of larger amount of alcohol was associated with a higher risk of stroke mortality even after adjustment of the data for other related risk factors. Results also indicated that intoxicating binge drinking increased the possibility of death from ischaemic stroke.[77] Similar results were reported on the associations between alcohol poisoning, accidents and cardiovascular diseases in Russian individuals who binge drink.[78] In contrast, results of recent case-control studies suggest that light to moderate alcohol consumption is associated with a reduction of the risk of ischaemic stroke, but heavy drinking led to an increased risk of ischaemic and haemorrhagic strokes.[79] The possible interaction between alcohol consumption and exercise training for 6.5 weeks on the brain antioxidant system was investigated in the rat. Exercise training appears to guard a specific brain region from alcohol-associated oxidative damage.[80]

4.2 Alcohol Use and the Cardiovascular System

Although the possible effects of alcohol consumption on the cardiovascular system have been an important topic of study for a very long time now, the results generated to date cannot be integrated into definitive general concepts. However, It is now well documented that chronic alcohol use is associated with adverse effects on the heart. Increasing evidence suggests that alcohol and its metabolite acetaldehyde directly impede cardiac muscle homeostasis.[81] Excessive alcohol use may cause cardiomyopathy and cardiac dysfunction. In alcoholic cardiomyopathy, dilation of the heart muscle and impaired contraction of the left or both ventricles has been reported.[82] Compared to age- and weight-matched controls, individuals with alcoholic cardiomyopathy exhibit an increase in left ventricular end diastolic diameters,[83] higher left ventricular mass index[84] and decreased left ventricular ejection fraction (<45%).[85]

It has been known for a long time that alcohol consumption results in cardiac rhythm disturbance; particularly supraventricular tachyarrhythmias (known as 'holiday heart' syndrome).[86] Not only chronic alcohol abuse, even a single heavy consumption might cause brief cardiac arrhythmias. The actual electrophysiological factors responsible for this phenomenon are not fully understood, but might encompass lowering the resting membrane potential[87] and prolongation of the electrical conduction within the heart muscle.[88] There is also convincing evidence that moderate-to-heavy alcohol consumption on a regular basis is the second most important lifestyle risk factor associated with the development of hypertension. Available data generated from observational and intervention studies suggest that alcohol consumption is responsible for the occurrence of 10% of hypertension in the Western male population.[89] Although the actual mechanism mediating this link is not fully understood, alcohol appears to interact with brain stem receptors, thereby exerting central hypertensive effects.[90]

Similar to strenuous exercise, alcohol consumption induces oxidative stress. The possible combined effects of chronic alcohol consumption and exercise training on the heart's antioxidant system was recently examined in the rat.[91] The data generated indicated that exercise training for 6.5 weeks attenuated the oxidative damage caused by alcohol consumption on the rat's heart.[91] It is possible that exercise training decreased alcohol-induced oxidative damage by up-regulation of the heart antioxidant capacity in parallel with a decrease in heart rate and blood pressure.

4.3 Alcohol Use and the Liver

Normal liver functions are essential for the regulation of the metabolic processes. Alcohol consump-

tion adversely affects the body's metabolism as the liver is the organ where alcohol is broken down and some of the metabolites generated such as acetaldehyde are very toxic to the liver. Furthermore, alcohol consumption is associated with oxidative damage, accumulation of free radicals and a depletion of the liver antioxidant capacity.[92] Women seem to be more vulnerable to the effects of alcohol than men.[93] Alcohol-induced liver diseases are a major cause of death in the Western world. Descriptive studies demonstrated that approximately 10–35% of heavy alcohol drinkers develop alcoholic hepatitis and 10–20% develop cirrhosis of the liver.[94] Liver cirrhosis due to chronic alcohol consumption accounts for approximately 10 000–24 000 deaths per annum in US.[95]

Impaired exercise capacity and oxygen consumption are common in patients with cirrhosis. For example, autonomic and cardiac dysfunction has been demonstrated in alcoholic patients with liver cirrhosis and exercise capacity was significantly impaired due to chronotropic incompetence. In addition, these patients exhibited no increase in left ventricular ejection fraction on exercise. It was concluded, therefore, that patients with alcoholic liver cirrhosis exhibit impaired cardiac and haemodynamic responses to exercise.[96] These results are consistent with earlier reports suggesting a link between impaired cardiac function and physical work capacity in patients with liver cirrhosis.[97] Recent research also confirmed this phenomenon in a study designed to determine the possible effects of myocardial dysfunction on exercise capacity in 39 cirrhotic patients and 12 age- and sex-matched healthy subjects.[98] The results indicated that exercise capacity in the cirrhotic patients was diminished and this was associated with myocardial thickening and ventricular stiffness leading to impaired diastolic function, inotropic and chronotropic incompetence. The conclusion may be that chronic alcohol consumption could seriously affect the normal liver functions and in some individuals cause cirrhosis. In addition, exercise capacity and oxygen consumption are impaired in patients with cirrhosis due to cardiac dysfunction.

5. Conclusion and Recommendations for Future Research

The aim of this review was to critically examine the published reports on the effects of alcohol use on the physiological and haematological profiles with an emphasis on exercise and sports. Despite the popularity and ecological importance of alcohol use and exercise throughout the world, particularly in the Western hemisphere, remarkably little is known about the combined effects of alcohol and exercise on the physiological and haematological consequences of these lifestyle habits. Numerous epidemiological and clinical studies have confirmed that both acute and chronic alcohol consumption is associated with a multitude of health problems. Available animal and human model studies on the effects of alcohol consumption have shown that alcohol can pathologically impair the normal physiological and haematological profiles. Although the acute effects of alcohol use on the body systems and organs is transient, the clinical implications of such effects need further investigation. While alcohol-related myopathy is well documented, exercise can attenuate some harmful effects produced by ethanol in the muscle such as the decrease in fibre area and capillary density. In light of the meagre data reported, no valid conclusion can be reached regarding the combined effects of alcohol use and exercise training on blood haemostasis, blood lipid profiles and blood rheology. This is undoubtedly due to the difficulties in designing these studies. An essential requisite in future studies should be controlled randomised trials with appropriate sample size. Furthermore, the possible preventative and therapeutic utility of exercise training to ameliorate the harmful effects of alcohol use warrants further investigations using standardised measurements. There are many stimulating areas of study for future endeavour in this field. Among other things, we need a better understanding of the mechanism(s) of interaction between alcohol and exercise and training.

Future directions for research are numerous, but the following fundamental questions warrant further investigation:

- Does exercise and training attenuate the harmful effects of alcohol ingestion on blood coagulation, fibrinolysis and platelets?
- The possible role of alcohol on blood rheology and blood lipids profile are inadequately established and further studies are warranted to unravel the exact effects of combining alcohol consumption and exercise on these systems.
- What is/are the mechanism(s) of interaction between alcohol use and exercise from the physiological and haematological viewpoints?
- If it is assumed that exercise and training reduce the harmful effects of alcohol consumption, how does this relate to the rate of incidence of cardiovascular diseases?

Current research by Professor El-Sayed and his research team is designed to address some of the above queries. It is hoped that these studies will guide a cornucopia of new research in the interaction between alcohol use and exercise in health and disease.

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