The Effect of Alcohol on Athletic Performance

Susan M. Shirreffs, PhD, and Ronald J. Maughan, PhD

Corresponding author
Susan M. Shirreffs, PhD
School of Sport and Exercise Sciences, Loughborough University, Leicestershire LE11 3TU, UK.
E-mail: s.shirreffs@lboro.ac.uk

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The use of alcohol is often intimately associated with sport. As well as providing a source of energy, alcohol (ethanol) has metabolic, cardiovascular, thermoregulatory, and neuromuscular actions that may affect exercise performance. Strength is minimally affected, and performance impairments depend on the dose of alcohol and subject habituation to alcohol intake, exercise duration, environmental conditions, and other factors. Central nervous system function is impaired at high doses, resulting in decrements in cognitive function and motor skill, as well as behavioral changes that may have adverse effects on performance. Effects may persist for hours after intoxication.

Introduction

Alcohol is not an essential part of the human diet, but various alcohols, of which the only one of quantitative significance is ethanol, are regularly consumed by a large part of the world's population. In addition to being a significant source of energy, providing about 7 kcal (29 kJ) per gram, ethanol has a number of effects that have implications for athletic performance. There are reasons to believe that acute alcohol intake may impair performance of endurance exercise because of effects on metabolic, cardiovascular, and thermoregulatory function. Performance of skilled tasks may be impaired because of effects on reaction time, fine motor control, levels of arousal, and judgment. All of these elements are important components of sports performance, but there are relatively few well-controlled studies of performance itself. The limited amount of experimental evidence is at least in part because institutional ethics review boards are reluctant to condone the administration of high doses of ethanol to volunteers. There have been rather few studies in this area in recent years, and there is an urgent need for further studies, particularly investigations involving measurement of sport-specific performance. In the past few years there appear to have been more review articles published on the effects of alcohol on sporting performance than original research papers. Recent reviews include those by Reilly [1], El-Sayed et al. [2], and Maughan [3].

In spite of the potential for negative effects on performance and health, there is ample evidence that alcohol features prominently in the lifestyles of many athletes at all levels of competition. There is evidence that at least some groups of athletes consume more alcohol than nonathletes, but separating fact from anecdote can be difficult. Data from a New Zealand student population show higher rates of hazardous drinking behaviors in elite athletes than in nonathletes [4]. There are data from France to show a lower prevalence of alcohol use in athletic students [5] and also data to show a greater prevalence of use [6]. Moore and Werch [7] have highlighted some of the complexities that influence analyses of the relationship between sports participation and substance use; in their survey, school-sponsored male-dominated sports were associated with increased alcohol use, but out-of-school, mixed-sex sports participation was associated with greater use in females. Reports that include only average intakes can be misleading, as binge drinking is commonly found in some team sports, and some athletes will abstain from alcohol in training but will drink copious amounts after competition [8]. The negative consequences of such excessive drinking may be greater for athletes than for their nonathletic peers [9]. These same authors have identified a number of reasons why athletes use alcohol, and identified three main factors, which they classified as *positive reinforcement*, *team/group*, and *sport-related stress*. Understanding the reasons for alcohol use is crucial in providing help to those whose intake is excessive.

Alcohol and Performance

Many of the studies on the effects of alcohol on athletic performance suffer from one of more defects. Subject numbers are often small, and the lack of a definite outcome may be the result of underpowered studies. The doses of alcohol that have been used in many studies are small relative to those reported to be consumed by ath-

Table 1. Net muscle glycogen storage (mmol/kg wet weight) after exercise depletion and recovery period with different diets

		Diet	
Recovery duration, *h*	**Control**	**Alcohol displacement**	**Alcohol + carbohydrate**
8	44.6 ± 6	24.4 ± 7	36.2 ± 8
24	81.7 ± 5	68.4 ± 5	85.1 ± 9

Data are mean ± SE.

letes. The reluctance of investigators to induce inebriation in their subjects, and the reluctance of ethics committees to sanction such studies because of safety concerns, are understandable, but this nonetheless limits the application of the studies to the real world of sport. It is not always clear that subjects have been fully familiarized with experimental protocols prior to measurements of performance, especially when tasks involving complex skills have been used. These factors may lead to performance changes that are of significance to the athlete being dismissed as being of no consequence [10].

The older literature on alcohol and athletic performance, and of those aspects of physiologic and metabolic function that contribute to performance, has been reviewed by Reilly [1] and Maughan [3] and are not repeated here. This review focuses on four areas in which there is some recent new information. These areas are carbohydrate metabolism, hydration and thermoregulatory function, the aftermath of alcohol use, and the effects of alcohol on injury and incapacity.

Effects of Ethanol on Glycogen Metabolism

Resynthesis of the glycogen stores in liver and muscle is one of the key goals of athletes after intensive training or competition, and it is well recognized that ethanol has a variety of effects on carbohydrate metabolism in skeletal muscle and liver. Much of the available evidence comes from older studies using animal models, showing that synthesis of glycogen in both liver and oxidative skeletal muscle is impaired in the presence of even relatively low levels of ethanol, though there seems to be no effect on type 2 muscle fibers. There is also evidence of impaired hepatic glucose output in the presence of even low doses of ethanol. This may be of particular concern during prolonged, moderate-intensity exercise when glucose output from the liver is an important source of energy.

Burke et al. [11•] reported the effects of alcohol intake on muscle glycogen storage in humans during recovery from a prolonged cycling bout that resulted in a substantial reduction of carbohydrate stores. Subjects undertook three different diets following their glycogen-depleting exercise: a high-carbohydrate diet intended to optimize recovery, an alcohol displacement diet (reduced carbohydrate, in which about 210 g of dietary carbohydrate was replaced by about 120 g alcohol), and an alcohol plus carbohydrate diet (about 120 g alcohol added to the high-carbohydrate diet). Muscle glycogen storage was significantly reduced (by almost 50% at 8 hours and about 16% at 24 hours) on the alcohol displacement diet when the amount of carbohydrate provided by the diet was less than optimal (Table 1). When the high-carbohydrate diet was eaten, however, there was no clear evidence that alcohol intake caused a reduction in muscle glycogen storage; there was a small, not statistically significant reduction at 8 hours and no effect at all at 24 hours. It should be noted that there was a large variability of the responses of different subjects, and it may well be that some individuals will be unable to effectively replenish their glycogen reserves between daily training sessions if substantial amounts of alcohol are consumed.

Even if there is not a direct metabolic effect of ethanol on glycogen storage when dietary carbohydrate intake is high, it is likely that athletes who consume large amounts of alcohol during the recovery period after training or competition will have a reduced carbohydrate intake, either as a result of a decreased total (nonalcohol) energy intake or because of a failure to follow the recommended eating strategies at this time.

Hydration and Thermoregulatory Function

The diuretic action of ethanol is well recognized, and Shakespeare referred to this in the drunken porter's response to Macduff [12]. Eggleton [13] quantified this effect, and estimated an excess urine production of about 10 mL for each gram of ethanol ingested. She also reported that the diuretic action was greatly attenuated, or eliminated altogether, in individuals who were already hypohydrated. Subsequent studies showed that alcohol acts via suppression of the release of antidiuretic hormone from the pituitary gland. Shirreffs and Maughan [14] confirmed the early report of Eggleton [13] when they showed that alcohol has a negligible diuretic effect when consumed in dilute solution following a moderate level of hypohydration induced by exercise in the heat. There appears to be no difference in recovery from dehydration whether the rehydration beverage is alcohol-free or contains up to 2% alcohol, but drinks containing 4% alcohol tend to delay the recovery process by promoting urine loss (Fig. 1). Based on the data of Eggleton [13], however, it is apparent that concentrated alcohol solutions will result in net negative fluid balance; a 25-mL measure of spirits (40% ethanol) contains 10 mL of alcohol and 15 mL of water, resulting in a urine output of about 100 mL and net negative water balance of 85 mL. Ingestion of large volumes of dilute alcohol will result in a water diuresis, but should promote restoration of fluid balance after sweat loss provided that there is also an intake of sodium, which is essential for restoration of euhydration [15].

The 1982 American College of Sports Medicine Position Stand on the use of alcohol in sports identified perturbations of thermoregulatory mechanisms, especially in the cold, as one of the reasons to abstain from alcohol prior to exercise. Small doses of ethanol given to human volunteers at rest in the absence of a thermal stress have very little effect on body temperature, but large doses administered before exercise at low ambient temperatures result in increased peripheral vasodilatation and a marked fall in core temperature. In combination with the concomitant fall in blood glucose concentration that is normally observed in this situation, there is clearly potential for an adverse effect on performance. Graham [16] showed that ingestion of alcohol (2.5 mL/kg) prior to prolonged (3 hours) exercise in the cold resulted in increased heat loss, though this effect was somewhat attenuated by co-ingestion of glucose. In animal studies, administration of alcohol to animals exposed to ambient temperatures both above and below the thermoneutral zone, has shown that alcohol acts to impair adaptation to both heat and cold [17].

In another animal study, rats were given 0, 4, 8, 12, or 16% ethanol as the sole source of drinking water for 14 days. Time to fatigue in treadmill running in the heat (35°C) of rats drinking 4% ethanol was similar to that of rats consuming water (32 vs 32.9 min, respectively), but running time of rats drinking 16% ethanol was reduced [18]. There seem to be no more recent studies in this important area. In view of the potential for adverse health consequences for athletes engaging in training and competition at climatic extremes, there does seem to be an urgent need for further studies in this area.

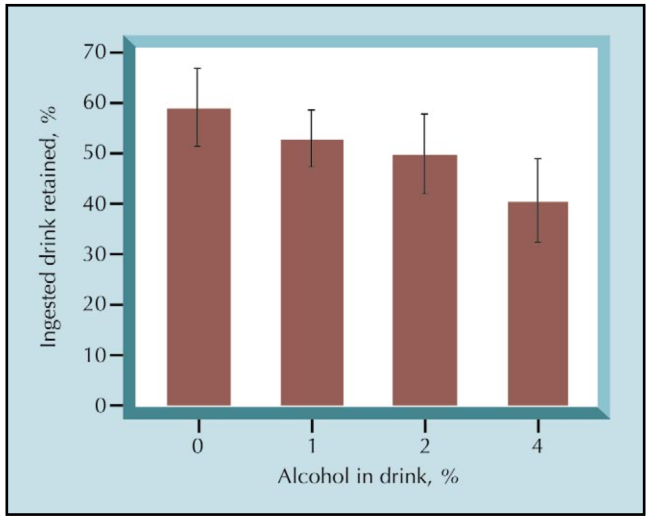

Figure 1. After exercise-induced dehydration, the fraction of ingested drink (containing 0%, 1%, 2%, and 4% alcohol) retained in the body and therefore effectively rehydrating the subject is influenced by the quantity of alcohol in the drink.

The Aftermath of Alcohol Use

There is limited and conflicting evidence on the effects of postalcohol consumption and hangover on functional capacity, but there is sufficient evidence of adverse effects the day after a heavy drinking session for such activities to be discouraged [19•]. O'Brien [20] showed reductions in aerobic exercise performance of rugby players the day after an evening bout of drinking involving an intake of 1 to 38 units of alcohol (equivalent to 10–380 mL pure alcohol), though anaerobic performance was unaffected. The negative effect on aerobic performance was apparent at even the smallest dose of alcohol. For obvious reasons, there are few studies of the effects of high alcohol intakes on soccer-specific performance, and there appear to be no studies on well-trained football players. In spite of substantial efforts on the part of the alcoholic drinks industry, the causes of the symptoms of hangover are not well understood, but are thought to include dehydration, acid-base disturbances, disruption of cytokine and prostaglandin pathways, and alterations in glucose metabolism via effects on circulating insulin and glucagon levels [21]. There are also disturbances of cardiovascular function during the hangover phase, including increased heart rate, decreased left ventricular performance, and increased blood pressure [22].

Effects of Alcohol on Injury and Incapacity

The ingestion of alcohol is likely to have a number of behavioral and other effects that may influence the risk of injury and the recovery process after injury. There are many reported instances of athletes in various sports competing while under the influence of alcohol, even though prior alcohol consumption appears to increase the risk of sports-related injury. According to O'Brien and Lyons [23], the injury prevalence in football players who habitually drink alcohol is higher (55%; $P < 0.005$) than in nondrinkers (24%). The mechanisms by which this association may be mediated are not entirely clear, but the increased risk of injury, and the increased severity of injuries that do occur, may be a consequence of increased risk-taking behaviors as alcohol removes some of the restraints that normally control behavior [20]. Increased levels of aggression are also often displayed by those under the influence of alcohol. Intoxication during competition is probably rather rare, at least at the higher levels of sport, though it is not completely absent. It is perhaps not so unusual, though, for athletes training the morning after a high alcohol intake the previous night to be still under the influence of alcohol, and several high-profile players from the various football codes (eg, soccer, rugby union, rugby league, Australian rules) have publicly admitted to alcohol addiction.

Athletes often experience some degree of muscle damage, either of intrinsic or extrinsic origin, after hard training or competition. This is usually in the form of minor damage that results in some degree of pain and disability that may persist for hours or days [24]. This damage results in turn in an inflammatory response that involves an increase in local blood flow and macrophage infiltration of the damaged area. Though minor, the accompanying symptoms may interfere with subsequent training or competition. Recommended treatments include application of ice, compression, and elevation of the limb to reduce blood flow. Because alcohol can act as a peripheral vasodilator, it is often stated that alcohol intake should be avoided after any exercise that may have resulted in muscle damage. There appears, however, to be no experimental evidence to support these anecdotal observations. In a prospective randomized trial, the effects of alcohol ingestion on exercise-induced muscle damage and soreness were investigated by Clarkson and Reichsman [25]. On one trial, women ingested alcohol (0.8g/kg) 35 minutes before performing single-arm eccentric exercise, with a nonalcoholic drink being taken in the other trial. Exercise resulted in muscle damage, as assessed by leakage of muscle-specific enzymes into the circulation, pain, loss of strength, and decreased range of motion on both trials, with no measurable effect of alcohol on any of these responses. It remains prudent, however, to avoid intoxication, as this is likely to result in inappropriate behaviors that may exacerbate existing muscle damage and delay the recovery process.

When more serious injury or surgical intervention results in longer-term inability to train or play, footballers may face some special problems. There may be a temptation to drink more, perhaps because of the absence of a requirement to prepare for upcoming games, or because of depression as a result of absence from the game and from the routine of training. This may result in unwanted weight gain, apart from the potential for negative effects on the repair process in muscle and other tissues.

Conclusions

Alcohol, as ethanol, is consumed by a significant number of athletes, as it is in the general population. Alcohol has been demonstrated to impact on exercise performance but the extent to which this occurs depends on many factors, including the exercise mode and duration and the individuals habituation to alcohol intake.

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1. Reilly T: **Alcohol, anti-anxiety drugs and sport.** In *Drugs in Sport*, edn 3. Edited by Mottram DR. London: Routledge; 2003:256–285.
2. El-Sayed MS, Ali N, El-Sayed AZ: **Interactions between alcohol and exercise: physiological and haematological implications.** *Sports Med* 2005, **35**:257–269.
3. Maughan RJ: **Alcohol and football.** *J Sports Sci* 2006, **24**:741–748.
4. O'Brien KS, Blackie JM, Hunter JA: **Hazardous drinking in elite New Zealand sportspeople.** *Alcohol Alcohol* 2005, **40**:239–241
5. Lorente FO, Peretti-Watel P, Griffet J, Grelot L: **Alcohol use and intoxication in sport university students.** *Alcohol Alcohol* 2003, **38**:427–430.
6. Lorente FO, Souville M, Griffet J, Grelot L: **Participation in sports and alcohol consumption among French adolescents.** *Addict Behav* 2004, **29**:941–946.
7. Moore MJ, Werch CE: **Sport and physical activity participation and substance use among adolescents.** *J Adolesc Health* 2004, **36**:486–493.
8. Burke LM, Maughan RJ: **Alcohol in sport.** In *Nutrition in Sport.* Edited by Maughan RJ. Oxford: Blackwell; 2000:405–416.
9. Martens MP, Watson JC 2nd, Royland EM, Beck NC: **Development of the athlete drinking scale.** *Psychol Addict Behav* 2005, **19**:158–164.
10. Hopkins WG, Hawley JA, Burke LM: **Design and analysis of research on sport performance enhancement.** *Med Sci Sports Exerc* 1999, **31**:472–485.
11.• Burke LM, Collier GR, Broad EM, et al.: **Effect of alcohol intake on muscle glycogen storage after prolonged exercise** *J Appl Physiol* 2003, **95**:983–990.

A research study investigating the effects of alcohol intake on postexercise muscle glycogen restoration, which concluded that although the direct effect of alcohol on postexercise glycogen synthesis is unclear, the main effect of alcohol intake is indirect, by displacing carbohydrate intake from optimal recovery nutrition practices.

12. Shakespeare W: *Macbeth.* Act II, Scene iii. London: Heminges and Condell; 1623.
13. Eggleton MG: **The diuretic action of alcohol in man.** *J Physiol* 1942, **101**:172–191.
14. Shirreffs SM, Maughan RJ: **Restoration of fluid balance after exercise-induced dehydration: effects of alcohol consumption.** *J Appl Physiol* 1997, **83**:1152–1158.
15. Shirreffs SM, Maughan RJ: **Water-electrolyte balance.** In *Encyclopaedia of Human Nutrition*, edn 2. Edited by Caballero B, Prentice A, Allen L. Oxford: Elsevier; 2005:100–105.
16. Graham T: **Alcohol ingestion and man's ability to adapt to exercise in a cold environment.** *Can J Appl Sport Sci* 1981, **6**:27–31.
17. Kalant H, AD Lê: **Effects of ethanol on thermoregulation.** *Pharmacol Ther* 1983, **23**:313–364.
18. Francesconi R, Mager M: **Alcohol consumption in rats: effects on work capacity in the heat.** *J Appl Physiol* 1981, **50**:1006–1010.
19.• Barker CT: **The alcohol hangover and its potential impact on the UK armed forces: a review of the literature on post-alcohol impairment.** *J R Army Med Corps* 2004, **150**:168–174.

A recent review of the literature relating to postalcohol impairment/alcohol hangover. Written from a military perspective, which is of relevance for exerciseing individuals, it concludes the evidence for performance impairment during alcohol hangover is not conclusive but there is the potential for impaired functioning, particularly the morning after a heavy drinking session, and even when blood alcohol has returned to zero.

20. O'Brien CP: **Alcohol and sport: impact of social drinking on recreational and competitive sports.** *Sports Med* 1993, **15:**71–77.
21. Wiese JG, Shlipak MG, Browner WS: **The alcohol hangover.** *Ann Int Med* 2000, **132:**897–902.
22. Kupari M: **Drunkenness, hangover, and the heart.** *Acta Med Scand* 1983, **213:**84–90.
23. O'Brien CP, Lyons F: **Alcohol and the athlete.** *Sports Med* 2000, **29:**295–300.
24. Clarkson PM, Hubal MJ: **Exercise-induced muscle damage in humans.** *Am J Phys Med Rehabil* 2002, **81:**S52–S59.
25. Clarkson PM, Reichsman F: **The effect of ethanol on exercise-induced muscle damage.** *J Stud Alcohol* 1990, **51:**19–23.