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Human Kinetics
SCHOLARLY REVIEW

Got Beer? A Systematic Review of Beer and Exercise

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Beer is used to socialize postexercise, celebrate sport victory, and commiserate postdefeat. Rich in polyphenols, beer has antioxidant effects when consumed in moderation, but its alcohol content may confer some negative effects. Despite beer's popularity, no review has explored its effects on exercise performance, recovery, and adaptation. Thus, a systematic literature search of three databases (PubMed, SPORTDiscus, and Web of Science) was conducted by two reviewers. The search resulted in 16 studies that were appraised and reviewed. The mean PEDro score was 5.1. When individuals are looking to rehydrate postexercise, a low-alcohol beer (<4%) may be more effective. If choosing a beer higher in alcoholic content (>4%), it is advised to pair this with a nonalcoholic option to limit diuresis, particularly when relatively large volumes of fluid (>700 ml) are consumed. Adding Na^+ to alcoholic beer may improve rehydration by decreasing fluid losses, but palatability may decrease. These conclusions are largely based on studies that standardized beverage volume, and the results may not apply equally to situations where people ingest fluids and food ad libitum. Ingesting nonalcoholic, polyphenol-rich beer could be an effective strategy for preventing respiratory infections during heavy training. If consumed in moderation, body composition and strength qualities seem largely unaffected by beer. Mixed results that limit sweeping conclusions are owed to variations in study design (i.e., hydration and exercise protocols). Future research should incorporate exercise protocols with higher ecological validity, recruit more women, prioritize chronic study designs, and use ad libitum fluid replacement protocols for more robust conclusions.

Keywords*:* alcohol, dehydration, performance, recovery, training

Beer is a yeast-fermented alcoholic beverage consisting primarily of water, malted cereals, and hops (Young, n.d.). Although its alcohol content can vary from <1% to over 15%, the typical beer contains about 5% alcohol by volume (Logan et al., 1999). In 2019, 65% of Americans drank alcohol, with beer topping the poll (Gallup, 2019). Beer consumption is also highly prevalent among sportspeople. At the collegiate level, athletes are more likely than nonathletes to drink beer (Overman & Terry, 1991) and binge drink (Nelson & Wechsler, 2001). Furthermore, nearly four in five female athletes of a Division I sample consumed alcohol, with light beer being the most popular beverage (Martin, 1998). In elite sports, former Finnish team athletes consumed more beer per month than controls (Kontro et al., 2017). Moreover, links between alcohol advertising and sport reenforce the strong connection beer has with athletes. For National Collegiate Athletic Association basketball tournament games from 1999 to 2008, all but five of 294 nationally televised alcohol advertisements were sponsored by beer or other malt liquor producers (Babor et al., 2013), and in 2012, beer ads made up 68.1% of all alcohol-related advertisements on sport TV programming in five major metropolitan centers of Australia (O'Brien et al., 2015).

There are various mechanisms by which beer could either positively or negatively impact acute and chronic exercise-related outcomes. Beyond its obvious detrimental effects on neuromotor function, high doses of alcohol impair muscle protein synthesis (MPS; Parr et al., 2014) and stimulate diuresis (Jones, 1990), which could lead to suboptimal training adaptions and rehydration, respectively. Then again, ingesting beer can acutely increase plasma antioxidant capacity, largely due to the absorption of phenolic acids (Ghiselli et al., 2000). However, beer's total antioxidant activity and polyphenol content depend chiefly upon the style of beer and its ethanol content (Piazzon et al., 2010). Prior research on polyphenols and exercise outcomes is mixed, but some data indicate they can positively impact performance (Somerville et al., 2017) and recovery (Myburgh, 2014). This suggests that, when consumed in moderation, beer could have some positive effects for people undertaking regular training.

Several reviews on alcohol and physical activity have been published previously (Barnes, 2014; Leasure et al., 2015; Piazza-Gardner & Barry, 2012). However, the broad scope of such reviews on multiple alcoholic beverages brings with it a limited focus, making it difficult to generalize about any particular beverage. Due to variations in alcohol content, phytochemistry, and nutrient profile, there are likely to be differences between alcoholic beverages regarding their effects on exercise-related outcomes. The present systematic review centered on beer's effects on exercise performance, adaptation, and recovery.

Methods

Overview

This systematic review was carried out to identify peer-reviewed experimental research that examined the effects of beer on exercise-related outcomes (performance, adaptation, or recovery). Studies of both an acute and chronic nature were of interest. Here, we define acute studies as ones in which beer ingestion and exercise occurred within 24 hr of each other. Chronic studies involved beer administration (or reduction in intake among regular consumers) for 1 week or longer. Furthermore, chronic studies also needed to have a regular exercise training (aerobic, resistance,

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interval, etc.) component to be included. Below are additional eligibility criteria:

(a) Types of studies: Randomized and nonrandomized human experiments.
(b) Participants: Individuals of legal drinking age able to complete exercise.
(c) Interventions: Administration of alcoholic or nonalcoholic beer acutely or chronically in conjunction with either acute exercise or chronic training. Studies that involved reducing habitual beer intake were also considered.
(d) Outcomes: Variables related to exercise performance, adaptation, or recovery were considered. Expressly, anthropometrics; body composition; MPS; muscle soreness; muscle damage; hydration status; time-trial performance; time to exhaustion; clinical outcomes (e.g., respiratory tract infections); physiological biomarkers (e.g., oxygen consumption, blood pressure, lipids, etc.); perceptual responses (e.g., exertion); and measures of muscular strength, power, or endurance were considered.

Review articles and those not available in English were excluded. Also, studies failing to clearly report beer dosage or timing of ingestion were excluded, as were theses, dissertations, conference abstracts, and articles reporting duplicate data.

Search Strategy and Data Extraction

Two reviewers independently searched three databases (PubMed, SPORTDiscus, and Web of Science) in October 2020. The search terms and strategy are listed in Table 1. The articles were screened first through title and abstract. If it remained unclear as to whether an article met the inclusionary criteria, the full text was read. After each reviewer completed their own search, they met to finalize the selected articles. The selected articles were evaluated in their entirety with applicable information extracted, including sample sizes, subject characteristics, research designs, independent variables (i.e., treatment and control conditions), and outcomes.

Study Quality

Randomized interventions were evaluated using the 11-item PEDro Scale (de Morton, 2009). Ten items are graded as 1 or 0 and totaled for a sum score. Previous studies have exhibited variability in the cutoffs for determining study quality (de Morton, 2009; Moseley et al., 2011). This review's classification system is listed in Table 2.

Synthesis/Presentation of Results

Studies were grouped based on acute or chronic design, given that beer's effects are likely to vary depending on whether it is ingested in one sitting or chronically (i.e., >1 week). For acute studies, outcomes were subgrouped based on categories (hydration, neuromuscular, etc.), while for chronic studies, outcomes were reviewed for studies individually, because there were only four studies and each had somewhat different outcomes. For all studies, the percentages preceding or following "beer" were used as shorthand to describe the alcohol content (e.g., 4% beer means beer that is 4% alcohol by volume).

Results

Initially, 22 articles appeared to be eligible. However, based on further discussion between the reviewers, six additional articles were excluded, with citations and reasons given in Supplemental Table 1 (available online). The search/selection process is shown in Figure 1. Fifteen of 16 included studies were scorable on PEDro (Figure 2). The mean score was 5.1, and three of 15 studies scored ≥6 (Figure 3).

Acute Studies—Samples

Twelve of 16 studies were acute in nature (Table 3). The groups recruited included professional soccer players (Castro-Sepulveda et al., 2016), recreational athletes (Desbrow et al., 2013; Desbrow et al., 2015), college students (Desbrow et al., 2019; Flores-Salamanca & Aragón-Vargas, 2014; Kruisselbrink et al., 2006), physically active males (Hobson & Maughan, 2010; Jiménez-Pavón et al., 2015; Rodrigues et al., 2019; Shirreffs & Maughan, 1997; Wijnen et al., 2016), and healthy males (Ka et al., 2003). Only two studies included females (Desbrow et al., 2019; Kruisselbrink et al., 2006); 13.5% of the participants were female. The mean ages ranged from 19.1 ± 0.4 to 36 ± 9 years. The sample sizes varied from six (Ka et al., 2003; Shirreffs & Maughan, 1997) to 54 (Desbrow et al., 2019).

Acute Studies—Exercise Tasks

For this section, "exercise task" refers to either experimental procedures (e.g., dehydrating exercise) or exercise-related outcomes (e.g., strength/balance testing). Seven studies used moderate to vigorous exercise to dehydrate participants to a target body mass loss before beverage administration (Desbrow et al., 2013, 2015; Flores-Salamanca & Aragón-Vargas, 2014; Hobson & Maughan,

Table 2 PEDro Scale Quality Classification

Quality	Low	Fair	Moderate	High
Sum score	0–3	4–5*	6–7	8–10

Note. Average PEDro sum score increased 0.6 per decade from 1960 to 2009 (Moseley et al., 2011).
*PEDro sum score mean: 5.1 (PEDro, 2020).

Table 1 Overview of the Search Strategy

Variables	Search terms
Group 1: Study design	randomized OR randomised OR randomly OR allocated OR placebo OR blinded OR "clinical trial" OR experiment OR controlled OR crossover OR "within subjects" OR "between subjects" OR "repeated measures" OR counterbalanc*
Group 2: Beer terms	beer OR lager OR ale OR "malt liquor" OR "alcoholic beverage" OR "alcohol free"
Group 3: Outcomes	exercise OR recovery OR hydration OR strength OR "physical activity" OR "muscle protein synthesis" OR "muscle soreness" OR "muscle damage" OR athlet* OR "body build*" OR sport* OR running OR cycling OR swimming OR sprint OR jump

Note. Groups were combined with "AND" (Group 1 AND Group 2 AND Group 3).

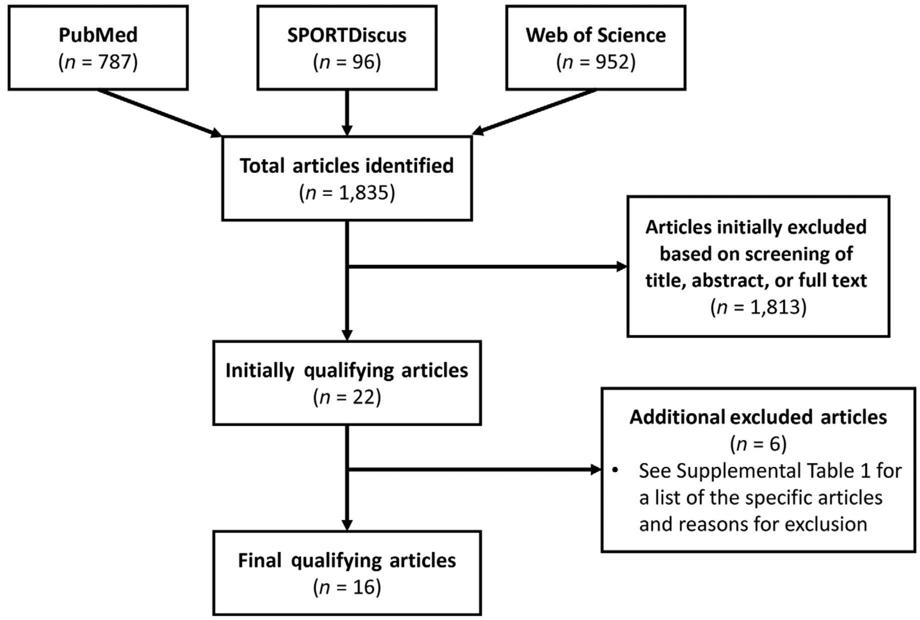

Figure 1 — An overview of the literature search and article selection process.

Study	1	2	3	4	5	6	7	8	9	10	11	Score
Castro-Sepulveda et al. (2016)	●	●	●	●	●	●	●	○	○	●	●	8
Cox et al. (1993)	●	●	○	●	○	○	○	●	○	●	●	5
Desbrow et al. (2013)	○	●	○	●	○	○	○	○	○	●	●	4
Desbrow et al. (2015)	○	●	○	●	○	○	○	○	○	●	●	4
Desbrow et al. (2019)	○	●	○	●	○	○	○	○	○	●	●	4
Flores-Salamanca and Aragón-Vargas (2014)	●	●	○	●	○	○	○	○	○	●	●	4
Hobson and Maughan (2010)	○	●	○	●	○	○	○	○	○	●	●	4
Jiménez-Pavón et al. (2015)	●	●	○	●	○	○	○	●	○	●	●	5
Kruisselbrink et al. (2006)	○	●	○	●	○	○	○	○	○	●	○	3
Molina-Hidalgo et al. (2019)	●	●	○	○	○	○	●	●	○	●	●	5
Molina-Hidalgo et al. (2020)	●	●	○	○	○	○	●	●	○	●	●	5
Rodrigues et al. (2019)	●	●	○	●	●	○	●	○	○	●	●	6
Scherr et al. (2012)	●	●	●	●	●	●	●	○	●	●	●	9
Shirreffs and Maughan (1997)	○	●	○	●	●	○	○	○	○	●	●	5
Wijnen et al. (2016)	○	●	○	●	○	○	○	●	○	●	●	5

Figure 2 — PEDro scoring for the 15 randomized experiments. Filled circles indicate the criteria is met, while open circles indicate the criteria is not met. Item 1 is not included in the final score.

2010; Jiménez-Pavón et al., 2015; Shirreffs & Maughan, 1997; Wijnen et al., 2016). Flores-Salamanca and Aragón-Vargas (2014) also conducted balance and reaction time outcome testing. Three studies utilized a set distance or time of aerobic exercise either before or after beverage ingestion (Castro-Sepulveda et al., 2016; Desbrow et al., 2019; Ka et al., 2003). Two studies employed either neuromuscular outcome testing alone (Rodrigues et al., 2019) or neuromuscular and aerobic outcome testing (Kruisselbrink et al., 2006).

Acute Studies—Beer Consumption Procedures

One study provided beverages 45 min preexercise (Castro-Sepulveda et al., 2016), while most used postexercise administration. Several studies divided beverage intake into equal doses throughout various time ranges (Desbrow et al., 2013, 2015; Flores-Salamanca & Aragón-Vargas, 2014; Kruisselbrink et al., 2006; Rodrigues et al., 2019; Shirreffs & Maughan, 1997; Wijnen et al., 2016), while two employed ad libitum drinking (Desbrow et al., 2019; Jiménez-Pavón et al., 2015).

In studies looking at postexercise consumption, the time between exercise cessation and consumption varied. One study had participants consume drinks in the morning after prior-evening exercise (Hobson & Maughan, 2010). Most studies, however, administered beverages starting no more than 30–60 min postexercise (Desbrow et al., 2013, 2015, 2019; Flores-Salamanca & Aragón-Vargas, 2014; Jiménez-Pavón et al., 2015; Ka et al., 2003; Shirreffs & Maughan, 1997; Wijnen et al., 2016).

Regarding beverage volume, the procedures varied between studies. When rehydrating postexercise, five studies had participants

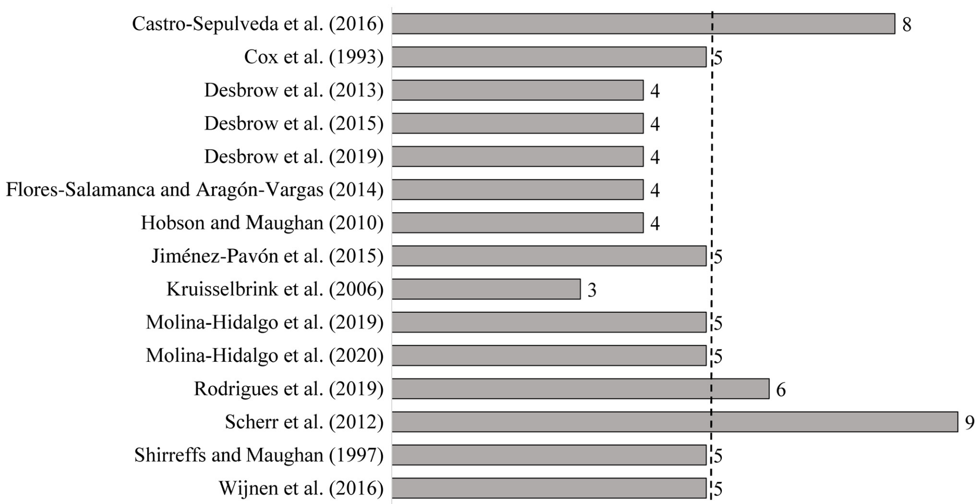

Figure 3 — Visual representation of relative study quality on the PEDro Scale. The dashed line represents the average value from the 15 scored studies.

drink to 150% (Desbrow et al., 2013, 2015; Shirreffs & Maughan, 1997) or 100% of body mass losses (Flores-Salamanca & Aragón-Vargas, 2014; Wijnen et al., 2016), whereas two studies utilized amounts expressed as grams or milliliters per kilogram of body mass (Ka et al., 2003; Rodrigues et al., 2019). Five studies employed drinking ad libitum (Desbrow et al., 2019; Jiménez-Pavón et al., 2015) or to a preset volume (Castro-Sepulveda et al., 2016; Hobson & Maughan, 2010; Kruisselbrink et al., 2006).

Acute Studies—Outcomes

The most relevant findings are discussed according to outcomes in the following subsections (also see Table 3).

Hydration. Regarding preexercise consumption, Castro-Sepulveda et al. (2016) found no between-treatment differences (percentage change from predrink to postexercise) or Time × Trial interactions for body mass, plasma Na^+ or K^+, or urine specific gravity when 700 ml of 4.6% beer, 0% beer, or water was consumed 45 min preexercise. There were also no differences in sweat rate.

Postexercise beer consumption affected hydration-related outcomes to varying degrees in all relevant studies (Desbrow et al., 2013, 2015, 2019; Flores-Salamanca & Aragón-Vargas, 2014; Hobson & Maughan, 2010; Shirreffs & Maughan, 1997; Wijnen et al., 2016) except Jiménez-Pavón et al. (2015). Jiménez-Pavón et al. (2015) reported a lack of between-condition differences in fluid balance, urine volume, urine solutes, hematological/serum parameters, and body composition when they examined ad libitum intake of 4.5% beer (up to 660 ml followed by water) or mineral water during a 2-hr postexercise period.

Hobson and Maughan (2010) found that, when participants consumed 0% or 4% beer in a euhydrated state in the morning after evening cycling, urine volume over 4 hr postconsumption was higher with 4% beer than 0% beer. However, no differences existed between 4% beer and 0% beer trials when participants were dehydrated. Also, at 1 and 2 hr postconsumption, serum osmolality was greater in both 4% beer trials than their hydration-matched 0% beer trials.

Shirreffs and Maughan (1997) evaluated how rehydration was impacted by postexercise beer consumption (equal to 150% of body mass losses) with differing alcohol contents (0%, 1%, 2%, and 4%). At 1 hr postrehydration, increases in blood and plasma volumes from prehydration were less with 4% beer than 0% beer, but at no other time were between-trial differences statistically significant. Although urine outputs over the 6-hr postrehydration period were not statistically different ($p = .307$), the median values (942, 1108, 1184, and 1457 ml) for 0%, 1%, 2%, and 4% beer conditions suggest a possible effect of alcohol content. The small sample ($n = 6$) likely undercut their ability to detect moderate-size differences.

Flores-Salamanca and Aragón-Vargas (2014) utilized a design similar to Shirreffs and Maughan's (1997), but they recruited 11 participants. On three occasions, the participants received water, 0.5% beer, or 4.6% beer after they had lost 2.1% of body mass. The volume administered (100% of body mass loss), however, was lower than Shirreffs and Maughan's (1997). Overall, the fluid retention was lower and urine output was higher over a 3-hr postconsumption period for 4.6% beer than other conditions.

Like Flores-Salamanca and Aragón-Vargas (2014), Wijnen et al. (2016) had participants replace exercise-induced fluid losses equaling 100% of body mass loss. However, they had five conditions (0% beer, 2% beer, 5% beer, sports drink, and water) versus three. The 5% beer increased urine output and worsened fluid balance versus sports drink at 1 hr posthydration, but these differences were not sustained 2–5 hr postconsumption. Notably, Wijnen et al. (2016) induced mild dehydration (1% body mass); consequently, fluid and alcohol consumed for the beer conditions were less than that consumed for Flores-Salamanca and Aragón-Vargas (2014).

Desbrow et al. (2019) had undergraduates consume 0.9% beer or Gatorade ad libitum after running 10 km. Gatorade was consumed in larger quantities than 0.9% beer (1.05 vs. 0.85 L) over 30–60 min and was rated higher for liking and refreshment. Furthermore, water intake over the rest of the day was higher with Gatorade than beer (3.34 vs. 2.98 L).

Two additional studies from Desbrow et al. (2013, 2015) examined interactions between the alcohol and Na^+ contents of beer. Their 2013 investigation found that, when 25 mmol/L Na^+ is added to 2.3% beer, it enhances postexercise rehydration (lower urine volume and better net fluid balance) relative to 4.8% beer, even if 4.8% beer contains 25 mmol/L Na^+. Desbrow et al. (2015) extended these findings by using a midstrength beer (3.5%), as well as by adding more Na^+ to low-alcohol beer. Urine volume over 5 hr

Table 3 Overview of Acute Studies

Article	Participants	Design	Exercise task	Groups/treatments	Drink schedule/ volume	Relevant outcomes	Notable significant ($p \leq .05$) findings
Castro-Sepulveda et al. (2016)	Seven male professional soccer players (age: 19.1 ± 0.4 years)	Double-blind randomized crossover trial	Treadmill running at 65% HR_{max} for 45 min	(1) 4.6% beer (2) 0% beer (3) Water	700 ml 45 min before start of exercise	BM, plasma Na^+ and K^+, urine volume, USG, and sweat rate	■ No between-treatment differences (% change, end-exercise, or postexercise) or Time × Trial interactions for BM, plasma Na^+ or K^+, or USG ■ No between-treatment differences in sweat rate or urine volume
Desbrow et al. (2013)	Seven male recreational athletes (age: 29.7 ± 4.3 years)	Randomized crossover trial	Cycling at 60% peak power until 1.9–2.0% of subjects' initial BM was lost	(1) 2.3% beer (2) 2.3% beer + 25 mmol/L Na^+ (3) 4.8% beer (4) 4.8% beer + 25 mmol/L Na^+	Drank 150% of change in BM, divided into four equal doses, each consumed over 15 min, starting 30-min postexercise	Urine volume, net fluid balance, gut perceptions, and drink palatability	■ Urine volume was lower with 2.3% beer + 25 mmol/L Na^+ than 4.8% beer and 4.8% beer + 25 mmol/L Na^+ over the entire 5-hr observation period ■ Net fluid balance was better with 2.3% beer + 25 mmol/L Na^+ than 4.8% beer and 4.8% beer + 25 mmol/L Na^+ at 3- and 4-hr postconsumption ■ Net fluid balance was better with 2.3% beer than 4.8% beer at 4-hr postconsumption ■ Beverage saltiness ratings were higher in the conditions with Na^+
Desbrow et al. (2015)	12 male recreational athletes (age: 24.2 ± 4.8 years)	Randomized crossover trial	Cycling at 60% peak power for 45 min, followed by self-selected intensity until 2% of subjects' initial BM was lost	(1) 2.3% beer + 25 mmol/L Na (2) 2.3% beer + 50 mmol/L Na (3) 3.5% beer (4) 3.5% beer + 25 mmol/L Na	Drank 150% of change in BM, divided into four equal doses, each consumed over 15 min, starting 30-min postexercise	Urine volume, net fluid balance, plasma aldosterone and arginine vasopressin, gut perceptions, and drink palatability	■ Urine volume was lower with 2.3% + 50 mmol/L Na^+ than the other three beverages over the entire 5-hr observation period ■ Net fluid balance was better with 2.3% beer + 50 mmol/L Na^+ than 3.5% beer at 2-, 3-, and 4-hr postconsumption ■ Net fluid balance was better with 2.3% beer + 50 mmol/L Na^+ than 3.5% beer + 25 mmol/L Na^+ at 3- and 4-hr postconsumption ■ Net fluid balance was better with 2.3% beer + 50 mmol Na^+ than 2.3% beer + 25 mmol/L Na^+ at 4-hr postconsumption ■ 2.3% beer + 50 mmol/L Na had lower flavor acceptability ratings than the other three beverages
Desbrow et al. (2019)	41 male and 13 female undergraduate students (age = 23.9 ± 5.8 years)	Randomized crossover trial	10-km run at a "sustainable pace"	(1) 0.9% beer (2) Gatorade (orange)	Consumed beverages ad libitum for 30–60 min postrun, with volumes measured by observers	Volume of drink consumption, BM, USG, urine color, thirst and hunger ratings, and drink palatability	■ Gatorade was consumed in larger quantities than 0.9% beer postexercise (1.05 vs. 0.85 L) ■ Gatorade was rated higher for overall liking and refreshment than 0.9% beer ■ Postexercise water intake for the rest of the day after the 10-km run was higher in Gatorade than 0.9% beer ■ Next-morning USG was slightly lower with 0.9% beer than Gatorade (1.016 vs. 1.021)

(continued)

Table 3 (continued)

Article	Participants	Design	Exercise task	Groups/treatments	Drink schedule/ volume	Relevant outcomes	Notable significant ($p \leq .05$) findings
Flores-Salamanca and Aragón-Vargas (2014)	11 physically active male college students (age: 24.4 ± 3.7 years)	Randomized crossover trial	Cycling at 70–85% of HR_{max} in hot conditions to achieve 2.1% BM loss	(1) Water (2) 4.6% beer (3) 0.5% beer	Consumed 100% of BM loss divided in four equal doses over four 15-min periods	Fluid retention, urine output, reaction time, and balance (center of pressure velocity)	■ Net fluid balance was 494–568 ml lower and urine output was 57–61% higher for 4.6% beer vs. other conditions over the entire 3-hr postconsumption monitoring period ■ Anteroposterior balance was impaired with 4.6% beer from the end of rehydration up to 90 min of follow-up vs. other two conditions ■ Postconsumption reaction time was slower with 4.6% beer than 0.5% beer
Hobson and Maughan (2010)	12 recreationally active males (age: 23 ± 4 years)	Randomized crossover trial	Intermittent cycling in the evening and hot-humid conditions until 1.9% BM was lost	(1) 0% beer in euhydrated state (2) 4% beer in euhydrated state (3) 0% beer in dehydrated state (4) 4% beer in dehydrated state	Consumed 1 L on the morning after evening exercise with or without fluid rehydration during the prior evening	BM, urine volume, free water clearance, serum and urine osmolality, urine electrolytes, urine pH, blood glucose, and plasma volume	■ Postdrink urine volume was higher with 4% beer than 0% beer when participants were euhydrated but not when dehydrated ■Urine pH levels in 0% beer trials were higher at 2-hr postdrink than their hydration-matched 4% beer trials ■ At 1- and 2-hr postdrink, serum osmolality was greater in both 4% beer trials than their hydration-matched 0% beer trials ■ At 2-hr postdrink, free water clearance was greater in both 4% beer trials than their hydration-matched 0% beer trials
Jiménez-Pavón et al. (2015)	16 physically active males (age: 21.1 ± 1.4 years)	Randomized crossover trial	Treadmill running at 60% VO_2-max in the heat lasting up to 60 min, with mean BM losses of 2.3–2.4%	(1) Mineral water (2) 4.5% beer + mineral water	Consumed mineral water ad libitum or 4.5% beer ad libitum (up to 660 ml) plus mineral water ad-libitum during 2-hr period postexercise	Total fluid intake, urine volume, DXA body composition, hematocrit, plasma electrolytes, plasma volume, urine osmolality, and urinary electrolytes and solutes	■ 4.5% beer + mineral water did not affect any measured outcome compared to mineral water
Ka et al. (2003)	Six healthy males (age: 30–39 years)	Nonrandomized repeated-measures trial	Cycling at 70% of VO_2max for 30 min	(1) Exercise with no beer (2) 5% beer alone (3) Exercise + 5% beer postexercise	Consumed 10 ml/kg of BM of beer; for the combined 5% beer and exercise condition, beer was consumed within 5-min postexercise	Plasma uric acid, plasma hypoxanthine, plasma xanthine, blood NH_3, blood lactic acid, urinary uric acid, urinary hypoxanthine, urinary xanthine, and creatinine clearance	■ Plasma uric acid increased more with exercise + 5% beer than with 5% beer alone or exercise alone ■ 1–2 hr after experimental manipulations (exercise, beer, or combination), blood lactic acid was higher in exercise + 5% beer than in 5% beer alone or exercise alone ■ Increase in plasma xanthine during 5% beer alone was 2.1-fold greater than during exercise + 5% beer condition

(continued)

Table 3 (continued)

Article	Participants	Design	Exercise task	Groups/treatments	Drink schedule/ volume	Relevant outcomes	Notable significant ($p \leq .05$) findings
Kruisselbrink et al. (2006)	12 female university students (22 ± 2.8 years)	Randomized crossover trial	A 6-min treadmill run at 6 mph, followed by running to exhaustion at 6 mph + 7% incline; a grip strength test was also administered	(1) No beer (2) Two 5% beers (3) Four 5% beers (4) Six 5% beers	Consumed 0, 2, 4, or 6 341-ml bottles of 5% beer the evening before morning exercise; beer was consumed over 30 min for each of the first two bottles, and 40 min for additional bottles	Choice reaction time, resting HR, resting BP, grip strength, running time to exhaustion, RPE, blood lactate, blood glucose, and hangover symptoms	■ On the morning after drinking, more choice reaction errors were made following six 5% beers compared to no beer and two 5% beers ■ On the morning after drinking, RPE during running to exhaustion was higher with four 5% beers than two 5% beers ■ No differences in resting HR, resting BP, grip strength, reaction time, and time to exhaustion ■ The number and intensity of hangover symptoms increased with each higher dose
Rodrigues et al. (2019)	10 physically active males (age: 23.5 ± 3.3 years)	Participant- and evaluator-blinded randomized crossover trial	Maximal strength and endurance of the knee extensors assessed with an isokinetic dynamometer	(1) 4.7% beer + sleep deprivation (2) 0% beer + sleep deprivation (3) 4.7% beer + normal sleep (4) 0% beer + normal sleep	Consumed 1 g/kg of BM of alcohol from 4.7% beer (or matched volume of 0% beer) on evening before morning exercise; 15–20% of volume consumed every 20 min for 2 hr	Isometric peak torque, concentric peak torque, endurance test time to failure, and muscle activation via electromyography	■ There was a 21% reduction in quadriceps activation during isometric peak torque for 4.7% beer + sleep deprivation compared to 0% beer + normal sleep ■ No differences observed in peak torque or endurance test time between the four trials
Shirreffs and Maughan (1997)	Six physically active males (age: 36 ± 9 years)	Participant-blinded randomized crossover trial	Intermittent cycling at 60% VO_2max in hot-humid conditions until 2% BM was lost	(1) 0% beer (2) 1% beer (3) 2% beer (4) 4% beer	Consumed 150% of BM loss starting 30-min postexercise; beer given in four equal volumes every 15 min for 1 hr	Urine output, urine electrolytes, net fluid balance, blood and plasma volumes, serum osmolality, and plasma vasopressin	■ At 1-hr postrehydration, increases in blood and plasma volumes from prehydration were less with 4% beer than with 0% beer, but at no other time were the differences between trials significant ■ Median urine outputs over the 6-hr postrehydration period were 942, 1,108, 1,184, and 1,457 ml in the 0%, 1%, 2%, and 4% beer conditions, respectively; this did not reach significance ($p = .307$), perhaps due to the small sample ■ The percentage of ingested fluid retained was 59.3, 53.1, 50.0, and 40.7 for 0% beer, 1% beer, 2% beer, and 4% beer (p value not listed)
Wijnen et al. (2016)	11 physically active males (age: 24.5 ± 4.7 years)	Randomized crossover trial	Cycling at 60% of maximal power output for ~45 min until 1% BM was lost	(1) 0% beer (2) 2% beer (3) 5% beer (4) Sports drink (5) Water	Consumed 100% of BM loss in three equal portions over 45 min following exercise	Urine output, net fluid balance, urine osmolality, and urine electrolytes	■ There was a Time × Treatment interaction for urine output during the postexercise period ■ Highest urine output occurred in 5% beer at 1-hr postrehydration, but urine output over the 5-hr postrehydration period did not differ (0% beer = 462 ml; 2% beer = 507 ml; 5% beer = 580 ml; sports drink = 444 ml; and water = 478 ml) ■ At 1-hr postrehydration, net fluid balance was lower in 5% beer than in sports drink; there were no differences at other time points ■ 5% beer led to a lower urine osmolality at 1-hr postrehydration than in sports drink ■ At 1-hr postrehydration, urine K^+ and Na^+ were lower with 5% beer than sports drink

Note. BM = body mass; BP = blood pressure; DXA = dual-energy X-ray absorptiometry; HR = heart rate; K^+ = potassium; Na^+ = sodium; RPE = rating of perceived exertion; USG = urine specific gravity; VO_2max = maximal oxygen consumption.

was lower with 2.3% beer that had 50 mmol/L Na^+ versus 2.3% beer with 25 mmol/L Na^+, 3.5% beer alone, or 3.5% beer with 25 mmol/L Na^+. Additionally, fluid balance was better at several time points with the 2.3% beer that had 50 mmol/L Na^+. Across both studies, the participants rated flavor as lower or drinks as saltier when Na^+ was added.

Neuromuscular performance. Two studies looked at the "hangover" effects of beer. The effects of 4.7% and 0% beers with or without sleep deprivation were evaluated by Rodrigues et al. (2019). In comparison to 0% beer combined with normal sleep, a significant 21% reduction in isometric quadriceps activation was observed with 4.7% beer and sleep deprivation. But no differences in performance (isometric peak torque, concentric peak torque, and endurance time to failure) were observed. Similarly, Kruisselbrink et al. (2006) reported that grip strength was not statistically different when the participants consumed zero, two, four, or six bottles of 5% beer the evening before the morning testing.

Beyond looking at the effects of water, low-alcohol beer (0.5%), and 4.6% beer on rehydration, Flores-Salamanca and Aragón-Vargas (2014) examined balance while each participant stood for 30 s on their left foot. Anteroposterior balance was impaired with 4.6% beer for 90 min postconsumption relative to other beverages.

Miscellaneous outcomes. Ka et al. (2003) looked at plasma uric acid following 30 min of cycling and whether ingesting 5% beer postexercise modified responses. Uric acid levels were highest following exercise plus 5% beer when compared to consuming 5% beer alone or exercise alone. When blood lactate was measured 1–2 hr postexercise, the levels were higher in the 5% beer–exercise condition than with beer alone or exercise alone.

Kruisselbrink et al. (2006) examined choice reaction time, as well as cardiovascular responses, blood markers, and rating of perceived exertion during submaximal and maximal running in females on the morning after the evening consumption of zero, two, four, and six bottles of 5% beer. Time to exhaustion was measured during maximal running. When subjects consumed four bottles, the rating of perceived exertion was higher compared with two bottles (17.9 vs. 17.1). For choice reaction time, subjects made more errors following the consumption of six bottles versus two and zero bottles (1.92 vs. 0.83 and 0.42. respectively).

Flores-Salamanca and Aragón-Vargas (2014) induced dehydration through cycling in hot conditions and tested reaction time after beverage rehydration by asking subjects to press a key as quickly as possible when an image was presented on a screen. The reaction time for 4.6% beer was longer (0.314 ± 0.036 s) than for 0.9% beer (0.294 ± 0.034 s), though the difference with water wasn't significant (0.293 ± 0.049 s, $p = .077$).

Chronic Studies—Samples

Four studies used chronic protocols (Table 4). Two of these reported different outcomes from a 10-week experiment that recruited men and women who were previously untrained (Molina-Hidalgo et al., 2019; Molina-Hidalgo et al., 2020). Scherr et al. (2012) enrolled runners training for a marathon, while the fourth study recruited sedentary men (Cox et al., 1993). In terms of sex, the Molina-Hidalgo et al. (2019, 2020) studies reported an almost identical proportion of males and females (~52% vs. 48%), with the remaining studies consisting of men. The mean/median ages ranged from 24 to 44 years. The sample sizes varied from 72 to 121 participants.

Chronic Studies—Exercise Components

The exercise components varied and included cycling (Cox et al., 1993), running (Scherr et al., 2012), and HIIT (Molina-Hidalgo et al., 2019; Molina-Hidalgo et al., 2020). The frequency of exercise ranged from two to three times/week (Cox et al., 1993; Molina-Hidalgo et al., 2019; Molina-Hidalgo et al., 2020), with one exception being Scherr et al. (2012), who did not incorporate a new exercise intervention, but enrolled runners preparing for the Munich Marathon. In terms of intensity, two involved HIIT (Molina-Hidalgo et al., 2019; Molina-Hidalgo et al., 2020), one study prescribed continuous exercise at low and moderate loads (Cox et al., 1993), and one allowed participants to self-select the intensity (Scherr et al., 2012).

Chronic Studies—Beer Consumption Procedures

One study looked at differences between low- and normal-alcoholic beer and provided 750-ml bottles that were consumed ad libitum over 4 weeks (Cox et al., 1993). Two articles reported results from a study that compared moderate intakes of normal beer, nonalcoholic beer, vodka, or sparkling water for 10 weeks (Molina-Hidalgo et al., 2019; Molina-Hidalgo et al., 2020). Finally, Scherr et al. (2012) compared consuming 1.0–1.5 L of nonalcoholic, polyphenol-rich beer to a low-polyphenol placebo over 5 weeks.

Chronic Studies—Outcomes

The outcomes had little overlap (Table 4); hence, each study is presented as a separate subsection.

Cox et al. (1993). Cox et al. (1993) used a two-way factorial randomized trial to evaluate whether the amount of alcohol consumed (six 750-ml bottles/week of 0.9% or 5.0% beer) modified adaptations to training (vigorous or light) in habitual moderate-to-heavy drinkers. Over 4 weeks, VO_2max increased by 10% with vigorous training, irrespective of the type of beer ingested. Systolic and diastolic blood pressures declined in the supine and standing positions (by roughly 2–5 mmHg) with 0.9% beer versus 5.0% beer. The groups receiving 0.9% beer also had decreases in serum triglycerides, high-density lipoprotein (HDL), apo A-I, and apo A-II, with an increase in total-to-HDL cholesterol ratio. A main effect of 0.9% beer was seen to reduce body mass by 0.43 kg, and there was a corresponding main effect of vigorous exercise on body mass (–0.43 kg). There did not appear to be interactions between beer type and exercise intensity.

Molina-Hidalgo et al. (2019, 2020). Two articles reported different outcomes from the same 10-week intervention, involving varying combinations of HIIT and alcohol intake. There were both randomized and nonrandomized aspects to the allocation. The participants first chose whether they were to be allocated to HIIT or no exercise. The participants who chose HIIT then chose whether to consume alcohol or not. Finally, the participants who chose alcohol were randomized to either 5.4% beer or a sparkling water–vodka mix, while those who chose no alcohol were randomized to 0% beer or sparkling water.

The 2020 article reported that VO_2max and exhaustion time increased in all four HIIT-beverage groups, with no change in the no-HIIT-no-beverage group. There did not appear to be pairwise differences in VO_2max changes between the four HIIT-beverage groups. When assessing neuromuscular outcomes, there were no group effects or Group × Time interactions for handgrip strength or

Table 4 Overview of Chronic Studies

Article	Participants	Design	Duration	Groups/treatments	Drink schedule	Exercise component	Relevant outcomes	Notable significant ($p \leq .05$) findings
Cox et al. (1993)	72 sedentary, habitually drinking men (age: 36.6 years)	Randomized 2 × 2 factorial trial with four groups	4 weeks	(1) 0.9% beer + light exercise (2) 5% beer + light exercise (3) 0.9% beer + vigorous exercise (4) 5% beer + vigorous exercise	6, 750-ml bottles of 0.9% or 5% beer supplied weekly	Two groups did 30-min sessions of cycling at low load 3×/week, while two groups did 30-min sessions of cycling at 60–70% of max workload 3×/week	BM, BMI, waist:hip ratio, VO_2max, heart rate, BP, serum lipids, serum catecholamines, hematocrit, urine sodium	■ Main effects of both 0.9% beer and vigorous exercise to reduce BM by 0.4 kg ■ VO_2max increased with vigorous exercise regardless of type of beer ■ 0.9% beer reduced supine and standing systolic and diastolic BP vs. 5% beer ■ 0.9% beer lowered serum triglycerides, HDL, apo A, and raised total cholesterol: HDL-cholesterol ratio vs. 5% beer
Molina-Hidalgo et al. (2019)	37 male and 35 female healthy adults (age: 24 ± 6 years)	Mixed (randomized and nonrandomized features) intervention with five groups	10 weeks	(1) 0% beer + HIIT exercise (2) 5.4% beer + HIIT exercise (3) Sparkling water–vodka mix + HIIT exercise (4) Sparkling water + HIIT exercise (5) No beverage or HIIT exercise	Drinks consumed Monday–Friday; men consumed 330 ml at lunch and dinner, while women consumed 330 ml at dinner	Participants who chose to do exercise ($n = 58$) did two HIIT sessions per week, while another group ($n = 14$) chose no HIIT exercise	BM, BMI, waist and hip circumference, waist:hip ratio, fat mass (kg, %), visceral adipose tissue, and bone mineral density	■ Increases in absolute lean mass occurred in all beverage-HIIT groups compared to the no beverage-no HIIT group ■ % fat mass decreased in 5.4% beer + HIIT, sparkling water + HIIT, and sparkling water-vodka + HIIT groups vs. the no beverage-no HIIT group ■ The % fat mass reduction in 0% beer + HIIT looked similar to the other HIIT groups but was not significantly different from the no beverage-no HIIT group
Molina-Hidalgo et al. (2020)	38 male and 35 female healthy adults (age: 24 ± 6 years)	Mixed (randomized and nonrandomized features) intervention with five groups	10 weeks	(1) 0% beer + HIIT exercise (2) 5.4% beer + HIIT exercise (3) Sparkling water–vodka mix + HIIT exercise (4) Sparkling water + HIIT exercise (5) No beverage or HIIT exercise	Drinks consumed Monday–Friday; men consumed 330 ml at lunch and dinner, while women consumed 330 ml at dinner	Participants who chose to do exercise ($n = 58$) did two HIIT sessions per week, while another group ($n = 15$) chose no HIIT exercise	BM, BMI, VO_2max, HR_{max}, exhaustion time, handgrip strength, vertical jump height	■ HIIT improved absolute and relative VO_2max and exhaustion time for all beverage-HIIT groups, with no pre–post changes in no beverage-no HIIT group ■ There was a time x group interaction for countermovement jump but not for other types of jumps or hand grip strength
Scherr et al. (2012)	121 male runners (median age: 42–44 years)	Double-blind placebo-controlled trial	5 weeks	(1) 0% beer with polyphenols (2) 0% beer without polyphenols	Consumed 1.0–1.5 L/day, 3 weeks before and 2 weeks after marathon	Participants did their own training leading up to running the Munich Marathon	Interleukin-6, blood counts, high-sensitivity C-reactive protein, and upper respiratory tract infection	■ Interluekin-6 was reduced in 0% beer with polyphenols immediately postmarathon vs. 0% beer without polyphenols ■ Total blood leukocyte counts were reduced in 0% beer with polyphenols immediately and 24-hr postmarathon vs. 0% beer without polyphenols ■ Incidence of upper respiratory tract infection was lower in 0% beer with polyphenols than 0% beer without polyphenols during 2 weeks postmarathon

Abbreviations: BM = body mass; BMI = body mass index; BP = blood pressure; HDL = high-density lipoprotein; HIIT = high-intensity interval training; HR = heart rate; VO_2max = maximal oxygen consumption.

jump heights, except for the countermovement jump, which showed a Time × Group interaction. Molina-Hidalgo et al. (2019) found similar increases in lean mass and decreases in fat mass in all four HIIT-beverage groups versus the no-HIIT-no-beverage group.

Scherr et al. (2012). For 3 weeks before and 2 weeks after the Munich Marathon, participants consumed 1.0–1.5 L/day of 0% beer with or without polyphenols. Immediately postmarathon, interluekin-6 and blood leukocyte counts were reduced in the polyphenol-rich beer group. Leukocyte counts at 24 hr postrace were also lower with polyphenol-rich beer. For 2 weeks postmarathon, the low-polyphenol beer group had 3.25 times the odds of experiencing an upper respiratory tract infection relative to the polyphenol-rich group.

Discussion

Acute Studies

When looking at acute responses to beer intake, there were mixed results, which is relatively unsurprising, given the variation in outcomes, types of beer consumed, and exercise tasks used. Of note, numerous studies from our review focused on hydration-related outcomes. Based on postexercise rehydration studies, choosing lower alcohol beer and/or adding Na^+ may aid with fluid retention, at least when fluid intake is standardized to body mass. Most studies reviewed, however, did not allow for an ad libitum rehydration strategy nor the consumption of food postexercise. When individuals are given the option to consume beverages with food ad libitum, the type of beverage may have less of an impact on fluid restoration (Campagnolo et al., 2017), whereas studies that standardize drink volume and do not provide access to food show that beverage composition considerably impacts fluid recovery (Hobson & Maughan, 2010; Shirreffs et al., 2007). As such, studies that do not consider ad libitum drinking and eating may give a misleading picture of a beverage's effects in real-world contexts. Ultimately, given that only two studies identified in this review used ad libitum drinking postexercise (Desbrow et al., 2019; Jiménez-Pavón et al., 2015), it is difficult to extrapolate the results to naturalistic settings in which people have more control over the volume of beer ingested as well as the coconsumption of food.

With this caveat in mind, several studies showed that, when normal beer (>4% alcohol) is consumed in standardized amounts postexercise, fluid balance and hydration are modestly worsened. Practically, this would be most problematic when an athlete has a brief recovery between exercise bouts, whereas the implications are unclear when there is >6–8 hr of recovery. Regardless, it is inadvisable to use normal alcoholic beer as the sole rehydration source when a fluid deficit of ≥1.5% of body mass is created. For example, a person weighing 75 kg would need to consume 1.13 L of beer to fully recover a body mass loss of 1.5%. The larger the dose of alcohol, the larger the diuretic effect (Jones, 1990). For individuals who wish to prioritize rehydration while consuming normal- or high-alcohol beer postexercise, they should consider drinking a limited amount (<700 ml) while focusing on coingestion of water, sports drinks, or other suitable rehydration beverages (e.g., milk). As shown by Jiménez-Pavón et al. (2015), mixing moderate beer intake (660 ml) with water may be just as effective as consuming water alone.

A variety of other factors that could impact the volume and type of beer ingested on any given occasion were not accounted for in the studies identified. First, one major consideration is that drinking guidelines and norms vary between countries and are influenced by national culture (Silva et al., 2017). Annual per capita beer consumption in Ireland in 2005, for example, was over 160 and <40 L in Italy, France, and China (Colen & Swinnen, 2011). Second, negative emotion (stress, anger, and depression) and poor emotional regulation strategies predict alcohol craving (Kim & Kwon, 2020). Similarly, positive interpersonal experiences can influence individuals to drink more socially (Mohr et al., 2001). These findings suggest that people are inclined to drink to cope with both positive and negative emotions. Practically speaking, this means that a person's emotional state in the postexercise period may impact the volume of beer ingested. Besides psychological and sociocultural factors, one must consider biological, intrinsic attributes, extrinsic sensory characteristics, and situational factors as well (Betancur et al., 2020). Virtually none of the studies identified in this review examined how these factors mediate beer consumption.

When it comes to fluid ingestion, there is a balance between what is considered palatable and physiologically recommendable. Desbrow et al. (2013, 2015) observed decreases in palatability or increased saltiness with added Na^+. To what extent does one make concessions in taste for the sake of recovery when that drink is consumed for pleasure? It is hypothetically possible that, under ad libitum conditions, people will consume less beer if it has substantial amounts of Na^+, which would undercut the benefit of the added sodium with respect to fluid balance. Consequently, future studies should evaluate the ad libitum consumption of Na^+-enriched beer postexercise.

The only study to have participants consume beer preexercise revealed no differences in body mass, plasma Na^+ or K^+, urine specific gravity, or sweat rate (Castro-Sepulveda et al., 2016). Alcohol consumption, even in moderate amounts, can negatively impact neuromotor functioning (Demura & Uchiyama, 2008). Consequently, preexercise alcoholic beer consumption is uncommon. Although alcoholic beer contains carbohydrate and fluid, the amount that would need to be consumed to meet standard preexercise recommendations for the intakes of these nutrients would be prohibitive. Whether nonalcoholic beer can serve as a suitable preexercise beverage has not been thoroughly studied. Nonalcoholic beer typically contains less carbohydrate by volume than sports drinks, and significantly less sodium.

For neuromuscular effects, alcoholic beer can be detrimental in several ways, at least when more than 1 liter is consumed. Balance is affected for up to 90 min postingestion (Flores-Salamanca & Aragón-Vargas, 2014), and reaction time is also impaired in the hours after consumption (Flores-Salamanca & Aragón-Vargas, 2014). In terms of next-day "hangover" effects, choice reaction time may be negatively affected with large doses of alcoholic beer (Kruisselbrink et al., 2006), and muscle activation could be negatively impacted when beer is mixed with sleep restriction (Rodrigues et al., 2019). In contrast, alcoholic beer does not seem to impact muscle strength or endurance when consumed the night before testing.

Chronic Studies

The reduction in upper respiratory tract infections in Scherr et al. (2012) suggests that polyphenols found in beer may exert antiviral and inflammation-reducing properties. This finding has implications, in that a 0% beer may be efficacious in preventing respiratory infections during heavy training or following strenuous competition. Whether these immune effects extend to alcoholic beer is undetermined, but the amount of nonalcoholic beer (1.0–1.5 L/day) used by Scherr et al. (2012) could be prohibitive if applied to beer with a normal or high alcohol content.

Moderate beer consumption seems to minimally impact cardiorespiratory- and strength-training adaptations, at least at the dosages studied. Molina-Hidalgo et al. (2020) found that a 10-week HIIT program improved muscular strength via handgrip testing, with no impairment among the 5.4% beer group. Similarly, VO_2max and treadmill time to exhaustion increased with HIIT, regardless of the type of beverage. This finding is in line with Cox et al. (1993), who found increases in VO_2max with vigorous exercise, regardless of whether normal- or low-alcohol beer was ingested. Still, caution is warranted in extrapolating these results to elite athletes or other types of training until more research is completed.

There is still ambiguity as to how beer intake influences body composition. Molina-Hidalgo et al. (2019) showed that moderate beer consumption (either from 5.4% or 0% beer) combined with HIIT did not lead to notable differences in body mass, body fat, or lean mass changes relative to HIIT with water or vodka. In contrast, Cox et al. (1993) found a small reduction in body mass when subjects switched from drinking normal to low-alcohol beer for 4 weeks. However, it is difficult to determine to what extent the small reduction in mass (−0.43 kg) would continue to accumulate over time. It is also essential to comment that beer's effects on body composition/weight may depend on the doses of exercise and beer. High daily dosages of alcoholic beer could impair lean mass accretion, given that binge drinking acutely interferes with post-exercise MPS (Parr et al., 2014) and that studies of chronic alcoholism show impaired MPS (Pacy et al., 1991). Furthermore, heavy beer drinking adds substantial energy to the diet, potentially resulting in body fat accumulation. Individuals doing large amounts of exercise may be somewhat protected from these effects, but this suggestion requires further study. Given the small number of studies on beer intake and weight/body composition in the setting of exercise training, it is premature to make strong conclusions. For now, it appears as if consuming 1–2 beers/day has negligible effects on body composition/weight.

Finally, Cox et al. (1993) examined changes to cardiovascular risk factors with alcoholic beer restriction and exercise among previously sedentary men. Switching to low-alcohol beer modestly reduced resting blood pressure, serum triglycerides, HDL cholesterol, and apolipoprotein A subfractions, regardless of the type of exercise (light vs. vigorous). It should be noted that participants were relatively heavy drinkers at the baseline (approximately 470–480 ml of ethanol/week), and intake was reduced by 85% with low-alcohol beer. Whether a modest change in intake would alter cardiovascular biomarkers is debatable, but some experimental evidence suggests it would (Chiva-Blanch et al., 2015).

Limitations

Most sample sizes were small, limiting the statistical power to detect small differences between conditions. Furthermore, most studies utilized continuous steady-state exercise to study the pre- or postexercise effects of beer ingestion on hydration. Future studies should incorporate exercise with varying intensities, durations, and types of exercise to increase ecological validity. It is difficult to blind subjects to alcoholic beverages, if not impossible, making certain outcomes more prone to bias. Dehydration was limited to various percentages of body weight, fluid replacement varied from 100% to 150% of body mass loss postexercise, and few studies used ad libitum drinking. Most of the research focused on men, and beer ingestion could differentially affect outcomes in women due to body size/composition, sweat rates, speed of alcohol metabolism, and so on. Finally, chronic studies lasted from 4 to 10 weeks, not an ideal amount of time when seeking to understand how beer affects body composition or fitness changes.

Conclusion

In general, low-alcohol beer seems to be more efficacious when individuals are looking to quickly rehydrate postexercise. Adding Na^+ to alcoholic beer may improve its rehydration properties, but there may be tradeoffs related to palatability. These conclusions are largely based on studies that standardized beverage volume, and the results may not apply to situations where people ingest fluids and food in an ad libitum fashion. When choosing a beer higher in alcoholic content postexercise (>4%), it is wise to pair it with nonalcoholic rehydration options to mitigate alcohol-induced diuresis, particularly when exercise-induced fluid losses are large. Nonalcoholic, polyphenol-rich beer has been observed to provide respiratory protection following a marathon, suggesting it could be a strategy for preventing respiratory infections during heavy training. Chronic changes in body composition, as well as muscle performance, adaptation, and recovery, seem largely unaffected by moderate beer consumption.

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