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The Dark Side of Alcohol: Implications for Muscle Growth, mTOR Pathway, and Athletic Recovery

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Abstract

Introduction and Objective: Alcohol is a prevalent substance in many cultures, often associated with socializing, relaxation, and even post-exercise rituals. Despite its widespread use, the effects of alcohol on muscle recovery and hypertrophy are not well understood by the general public. Emerging research suggests that alcohol may have negative health effects on these factors. Understanding the interaction between alcohol consumption and resistance training is crucial for athletes and individuals aiming to optimize their fitness outcomes.
The main aim of this article is to show clinicians, patients and, above all, athletes, the negative effects of alcohol on training and leading a healthy lifestyle.

Review and Methods: Review and summary of studies and meta-analysis of studies available in open-source format on Google Scholar, Web of Science and PubMed.

Abbreviated Description of the State of Knowledge: Resistance training is a proven method for increasing muscle mass and strength through the process of hypertrophy, where muscle protein synthesis (MPS) exceeds muscle protein breakdown (MPB). The mechanistic/mammalian target of rapamycin (mTOR) signaling pathway plays a key role in regulating MPS and hypertrophy.

Summary: Alcohol has been shown to impair muscle protein synthesis, primarily through its negative effects on the mTOR signaling pathway, which is crucial for muscle growth. Additionally, alcohol disrupts sleep quality, further hindering recovery and performance.

Keywords: resistance training, alcohol consumption, muscle hypertrophy, mTOR signaling, muscle protein synthesis, recovery, sleep quality, exercise performance, high-intensity interval training, athletic performance.

Introduction

Resistance training is a widely recognized and effective method for promoting muscle hypertrophy, strength, and overall fitness. The process of hypertrophy is driven by an increase in muscle protein synthesis (MPS), particularly following mechanical stimulation through exercise. The mTOR (mechanistic/mammalian target of rapamycin) signaling pathway plays a crucial role in regulating this synthesis, responding to stimuli such as nutrient availability, growth factors, and mechanical stress. However, external factors, such as alcohol consumption, can negatively impact this finely-tuned process [1-2].

Alcohol, a commonly consumed substance, is known to have detrimental effects on muscle growth and recovery. It has been shown to impair MPS, primarily by disrupting the mTOR signaling pathway, which is vital for muscle growth and adaptation following resistance training [1]. Furthermore, alcohol negatively affects sleep quality, recovery, and overall performance, posing challenges for athletes and fitness enthusiasts seeking optimal results [11-21]. Despite these potential drawbacks, research indicates that physically active individuals tend to consume more alcohol than their sedentary counterparts, raising important questions about the balance between exercise and lifestyle choices [1][16-20].

This article reviews the current literature on the effects of alcohol consumption on muscle hypertrophy, the mTOR signaling pathway, and recovery. It also explores the social and behavioral trends linking alcohol use with physical activity, providing insights into how alcohol intake might influence exercise adaptations and long-term athletic performance.

Materials and methods

A comprehensive review of the scientific literature on alcohol implications for muscle growth, mTOR pathway, and athletic recovery was conducted. A systematic search was performed using the PubMed, Google Scholar, and Web of Science databases. The inclusion criteria encompassed articles written in English, including original research studies, meta-analyses, clinical trials, and review articles. Articles written in languages other than English, case reports, commentaries, and letters were excluded from the review. The remaining publications were then assessed for their relevance and appropriateness for inclusion in this study.

Resistance training-impact of alcohol on hypertrophy

The size of skeletal muscles is the effect of muscle protein breakdown and muscle protein synthesis. When synthesis is bigger than degradation, the process is known as hypertrophy. Regular resistance training is a widely recognized and effective way to enlarge the size of the muscle. Protein synthesis rises after exercise and can last 24-48h. Resistance exercise also increases protein breakdown, but if enough mechanical stimulation and nutrient intake are provided, the increase in synthesis exceeds the increase in breakdown.

Alcohol, unlike resistance exercise, decreases protein synthesis. Measurements of the gastrocnemius and plantaris muscles, using 35S-methionine/cysteine incorporation 2.5 hours after consuming alcohol showed reduction in protein synthesis, while measurements using 35S-methionine/cysteine release showed no change in protein breakdown. Chronic alcohol use is

associated with similar effects [1]. Consequently, alcohol can negatively affect hypertrophy following resistance training, even if optimal nutrients are provided [2].

Resistance training and alcohol consumption-the impact on mTOR signaling pathway

The most important signaling pathway for protein synthesis and hypertrophy among cell signaling mechanisms is the mechanistic/mammalian target of rapamycin complex 1 (mTORC1) pathway. The mTOR signaling pathway occurs through two multiprotein complexes: mTORC1 and MTORC2. Transmission of signal by mTORC1 is responsible for cell growth and metabolic activity, whereas mTORC2 is associated with cytoskeletal maintenance and cell survival [1].

The importance of mTOR has been demonstrated using rapamycin-mTORC1 inhibitor. Rapamycin, taken after intense exercise involving a series of high-intensity muscle contractions, blocked the early increase of muscle protein synthesis. Many biochemical changes in phosphorylation were observed compared to the control group. As a result, early protein synthesis decreased after blocking mTOR signaling pathway [3].

Probably mTORC2 cooperates with mTORC1 in protein synthesis following resistance training; however, its role is less understood compared to mTORC1. When mTORC2 was also inhibited, both early and late muscle protein synthesis were suppressed [4].

The mTOR signaling pathway receives and processes mechanical stimuli, signals from growth factors, and nutrients. The kinase remains inactive when resources are insufficient or under stressful conditions. However, in nutrient-rich and growth-promoting environments, the kinase becomes active. Results of activating mTOR cell signaling pathway are: translation initiation, peptide elongation, ribosomal biogenesis, suppression of autophagy and eventually protein synthesis [1].

Ethanol and resistance exercise are factors which can affect mTOR pathway, resulting in either decreasing or increasing protein synthesis [1]. Studies have shown a negative impact of alcohol on mTOR signaling resulting in reduction of protein synthesis [5-9].

In one study, 10 resistance-trained male and 9 resistance-trained women performed the same heavy resistance training and later consumed alcohol or a placebo. To investigate the alcohol impact on muscles, biopsies from the vastus lateralis were taken before and after exercise. The biopsy specimens were analyzed for phosphorylated mTOR, S6K1, and 4E-BP1. In men mTOR phosphorylation was significantly higher in the placebo group, indicating better protein synthesis. The findings from the study suggest that consuming alcohol after a workout can negate the desired effects of exercise [10]. Additionally, alcohol impairs protein synthesis by disrupting the response to stimuli: leucine, insulin, and IGF-1.

Alcohol and resistance training impact the mTOR pathway but in different ways and have opposite effects on protein synthesis- generally, exercises stimulate, ethanol suppresses it. It implies that alcohol could potentially disrupt exercise adaptations [1].

Sleep, recovery, hangover

It is commonly believed that alcohol helps falling asleep, but in fact ethanol impairs sleep quality. Even if doses of alcohol are moderate, such as less than 1g/kg body weight, REM sleep phase shortens. When alcohol consumption is higher, falling asleep becomes more difficult,

the percentage of time spent sleeping decreases, and waking up after sleep onset becomes more likely [11]. When blood alcohol levels drop during the night, it can cause arousal.

Alcohol use before sleep also can cause obstructive sleep apnea, which is the next factor disturbing sleep and reason for fatigue on the next day [12]. People with higher alcohol use report lower sleep quality, shorter sleep duration and snoring more often than non-drinkers [13-14].

Sleep and its quality is crucial for physically active individuals. It regulates numerous functions of organisms. It is also involved in muscle recovery after training. Adults should sleep 7-9 hours, but athletes may require even more sleep to recover, as their nervous system and muscles are more stressed than in the general population. If sleep is impaired, it may cause decreased muscle protein synthesis, reduced anabolism and increased catabolism. Additionally, it leads to higher levels of cortisol and dysregulation of appetite [15]. Brain function and decision-making also worsen, all of which can impair sports performance. Even a reduction in sleep by 2-4 hours can have a negative impact. Tests conducted after sleep deprivation showed a decline in running performance, lover muscle glycogen levels and reductions in submaximal strength, isokinetic peak torque, minute ventilation, distance covered, sprint times, tennis serve accuracy, soccer kicking skills, and time to exhaustion. Cognitive function was also impaired with reaction times lengthened [16]. Moreover, sleep deprivation can cause more painful DOMS (delayed onset muscle soreness) after workout due to altered pain perception [17].

The study among women showed that decision making was significantly impaired in the day following moderate ethanol consumption [18]. Due to hangovers cognitive and psychomotor function as well as mood are impacted negatively. Also people tend to decrease their physical activity as a result of this condition [19]. Endurance is impaired. In the study, the group that consumed alcohol the day before a 15.8 km hike reported greater exhaustion than the non-drinking group despite the same level of exertion [20]. Alcohol consumption the day before significantly impairs performance in high-intensity exercise the following morning. However there was no notable change in strength and power [21].

To sum up, alcohol can negatively impact sports performance by shortening sleep and decreasing its quality.

BEER-HIIT study

HIIT, or High-Intensity Interval Training, consists of short bursts of intense, dynamic exercises alternated with brief rest periods. Due to its intensity, it is short in duration, making it time-efficient. However, it also offers other benefits such as improving cardiovascular function, increasing endurance, reducing appetite and eventually enhancing body composition [22].

The BEER-HIIT study investigated effects of combining moderate, regular alcohol consumption HIIT. Ethanol intake was 1.7–2.6 standard drinks per day for men and 0.9–1.7 for women. Control group consumed non-alcoholic beer or sparkling water. Exercises were performed twice a week. Before and at the end of the study anthropometric measurements and body composition were assessed using dual-energy X-ray absorptiometry. The trial lasted 10 weeks and showed that body composition and bone mineral density weren't negatively affected. Additionally, all groups experienced decreased fat mass and increased lean mass [23]. The

BEER HIIT study also examined the impact of HIIT and moderate alcohol use on cardiorespiratory fitness, muscle strength and power parameters. Maximal oxygen uptake in absolute and relative terms (VO2max.), maximal heart rate, total test duration, hand grip strength and four types of vertical jumps were measured before and after trial.
After 10 weeks all groups improved VO2max and grip strength. To sum up, moderate alcohol use did not reduce positive effects of HIIT [24].

Alcohol use among physically active individuals

Paradoxically, studies show that people with sedentary lifestyles consume less alcohol compared to physically active individuals [1]. A research among young adults found that increasing physical activity is associated with increased alcohol consumption, but only during the first 9 months. After this time the change is not significant. On the other hand, increasing alcohol consumption is correlated with simultaneous increase in time spent on physical activity [25]. Another study revealed that college students, who exercised more also drank more alcohol [26]. A national survey in America found that individuals who consumed alcohol were more active than non-drinkers. Drinking was particularly associated with vigorous exercise [27]. Another study investigated binge drinking among students, finding that college athletes reported alcohol consumption more often than non-athletes, likely due to the perception of alcohol consumption as more socially acceptable [28]. Vast majority of athletes did not report concerns that ethanol would impair their performance or negatively affect their health [29]. Additionally, drinking alcohol may serve as a way to foster group identity [30] and can positively influence social interactions [31]. Drinking alcohol as a reward after competitions is a common practice, particularly among sub-elite athletes. In contrast, elite athletes appear to have less time for leisure and tend to adhere more strictly to their tight schedules [24].

Conclusions

The paradoxical trend of higher alcohol consumption among physically active individuals suggests that lifestyle choices may counteract the benefits of exercise. Therefore, it is crucial for athletes, trainers, and healthcare professionals to understand the potential risks associated with alcohol consumption and to encourage practices that support both physical and overall well-being. Future research should continue to explore the nuanced relationship between alcohol use, physical activity, and long-term health outcomes to provide clearer guidelines for those seeking to optimize their training results while maintaining a balanced lifestyle.

Disclosure

Author's contribution

Conceptualization, Anna Dobosz and Wiktoria Zduńczyk; methodology, Ada Żydek, Urszula Ciułek and Michalina Dubińska; software, Urszula Ciułek; check, Wiktoria Zduńczyk, Anna Dobosz and Wiktoria Bilska; formal analysis, Ada Żydek, Michalina Dubińska; investigation, Wiktoria Paduch-Jakubczyk; resources, Wiktoria Paduch-Jakubczyk Anna Dobosz and Wiktoria Bilska; data curation, Michalina Dubińska; writing - rough preparation, Anna Dobosz, Wiktoria Paduch-Jakubczyk and Wiktoria Bilska; writing - review and editing, Wiktoria Zduńczyk, Michalina Dubińska and Urszula Ciułek, Ada Żydek; visualization, Wiktoria Bilska;

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