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CANNABIS AND EXERCISE PERFORMANCE: CURRENT EVIDENCE

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KEY POINTS

- Despite remaining on the prohibited substance list of the World Anti-Doping Agency, the use of cannabis is widely reported among athletic populations for both recreational and performance-related purposes.
- Molecules unique to cannabis are known as cannabinoids, each of which exerts varied effects through cannabinoid receptors.
- Cannabis can be consumed in different ways, with method of consumption and cannabinoid composition modulating the drug's effects.
- There is currently limited applicable evidence regarding the physiological effects of cannabis during exercise or the impact on performance. Understanding the short- and long-term effects of cannabis on human performance requires targeted and well-controlled athlete-specific investigations with applied performance outcomes.
- It is currently unclear if cannabis is ergogenic, ergolytic, or has no meaningful effect on performance.

INTRODUCTION

Cannabis is one of the most widely used recreational substances in the world, second only to alcohol (United Nations Office on Drugs and Crime, 2020). With an increasing number of governments legalizing recreational use, mainstream acceptance of cannabis is evolving, and the scientific study of cannabis administration to affect psychological and physiological functioning is expanding to include applications in medicine and beyond. This includes potential applications for athletic performance, but the empirical case for or against cannabis use in sport remains unclear due to regulatory barriers, which have limited its study (Haney, 2020).

CANNABIS USE

While there is a paucity of scientific support for the combination of cannabis use with exercise, accounts of its use among athletes are common (Brisola-Santos et al., 2016; Lorente et al., 2005; Peretti-Watel et al., 2003). This includes both recreational cannabis use, as well as consumption with the intention of gaining a competitive advantage. There is longstanding evidence that cannabis has the capacity to alter cardiorespiratory physiology at rest (Jones, 2002; Ribeiro & Ind, 2016), which fuels speculation that cannabis could also affect exercise capacity. Furthermore, the known psychological effects of cannabis use, including its influence on arousal, anxiety, recovery, decision making, and motor control could have implications for sport performance (Close et al., 2021; Kvålseth, 1977; Lorente et al., 2005). Recent data surveying almost 50,000 athletes of varying age and ability show that almost 25% of respondents reported using some form of cannabis within the past year (Docter et al., 2020). Current patterns of use among athletes are associated with the type of sport (including individual vs. team sport), competition level, gender, and demographic characteristics (Brisola-Santos et al., 2016; Lorente et al., 2005; Peretti-Watel et al., 2003). Notably, there is also a relation between using cannabis as a recreational drug and the chances of seeking to use it to enhance some aspect of sport performance (Lorente et al., 2005). The high prevalence of cannabis use, in both athletes and the general population, warrants education on use for individuals, coaches, and (sport) scientists. While there are very real issues surrounding suitability, safety, and ethical use of cannabis in sport, the focus of this Sports Science Exchange article is to explore the effects of whole cannabis use, and one of its most abundant cannabinoids, delta-9-tetrahydrocannabinol (THC), on human physiology and exercise performance. The use of cannabidiol (CBD), another prominent cannabinoid, which is no longer a World Anti-Doping Agency (WADA) banned substance, is addressed in a companion article with respect to claims, evidence, prevalence, and safety concerns (Close et al., 2021).

CANNABIS AND CANNABINOIDS

Cannabis contains over 100 genus-specific molecules, known as phytocannabinoids (Amin & Ali, 2019). While it is possible that each influences human physiology in some capacity, the two most widely studied and relevant are THC and CBD. The relative abundance of phytocannabinoids varies across cannabis variants, with products popular for recreational use commonly targeting higher THC content, as THC is responsible for the psychotropic effects of cannabis (Amin & Ali, 2019; Ashton, 2001). THC acts as a partial agonist to the putative endogenous cannabinoid receptors type 1 (CB1) and 2 (CB2), which are located in a wide range of central and peripheral tissues (Anand et al., 2009; Pertwee, 1997). While CBD does not have psychotropic properties, there is evidence that it may modulate the effects of THC (Anand et al., 2009). At present, the full range of receptor targets of these two cannabinoids is not completely characterized, and each may exert physiological actions outside of CB1 and CB2 pathways (Pertwee, 2008). THC and CBD are typically the two most abundant cannabinoids in cannabis products due to consumer demand. This has led to the alteration of cannabinoid ratios in cannabis products over time, with products today having much higher concentrations of these key cannabinoids than what had been traditionally available (Ashton, 2001).

CANNABIS CONSUMPTION

Cannabis can be consumed in various ways, and the exogenous dose of individual cannabinoids will depend on the cannabinoid concentrations within the product that is consumed, whether it be whole cannabis or derivatives such as edible products. While there is a long history of dried cannabis flower being consumed via inhalation of smoke from combusted material in a pipe, joint, or bong, which leads to rapid uptake and effects (Huestis et al., 1992), methods such as aerosol inhalation (commonly known as vaporization) and ingestion are becoming more common with the development of commercially available products. When ingested, as opposed to inhaled, absorption through the gut delays uptake (0.5-1 hour), with peak effects occurring 1.5 to 3 hours post-consumption (Schlienz et al., 2020). With increasing acceptance of recreational use in many countries, it is expected that the diversity of commercially available options for consumption will continue to grow as markets expand.

PHYSIOLOGICAL EFFECTS OF CANNABIS

The systemic physiological effects of cannabis on humans have mostly been characterized during rest. Apart from the well-documented psychotropic effects, the majority of research has considered the role cannabis plays in altering cardiovascular and respiratory function (Figure 1). Evidence suggests that cannabis consumption leads to a wide range of transient effects, including alterations in heart rate and function, resting blood pressure, orthostatic control, respiratory sensitivity, and bronchodilation (Jones, 2002; Malit et al., 1975; Tashkin et al., 1977). It is recognized that many of the noted cardiovascular effects that occur with cannabis or THC administration, such as increased resting heart rate, hypertension or hypotension, and orthostatic hypotension, are diminished with more consistent use, as tolerance builds within days or weeks of regular use (Benowitz & Jones, 1975). Notably, most of the longstanding evidence comes from studies that used smoking as the sole method of consumption, and it is well accepted that smoke and carbon monoxide inhalation independently have a number of cardiovascular effects associated with both transient and persistent alterations to function. However, studies that administered THC in isolation showed that many of these observed effects still occur, including alterations in limb blood flow (Benowitz et al., 1979; Weiss et al., 1972), heart rate (Benowitz & Jones, 1975; Isbell et al., 1967), blood pressure (Benowitz & Jones, 1977; Benowitz et al., 1979), and ventilatory sensitivity (Malit et al., 1975), with a likely role of alterations in the autonomic nervous system control. In any event, the observed effects give credence to speculation that these systems-level alterations could affect performance by altering the physiological response to exercise.

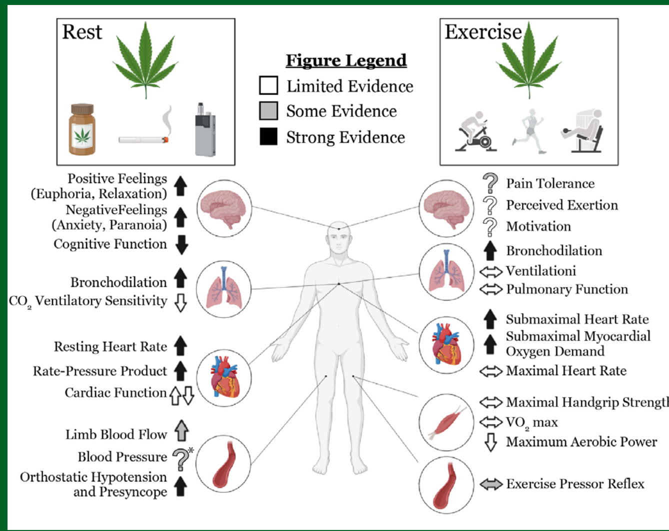

Figure 1: The systemic effects of cannabis consumption, at rest (left) and combined with exercise (right), with the arrows representing the expected direction of the effect and strength of current evidence. *Reports of the effects of cannabis on blood pressure indicate a wide range of possible effects. (Figure created with BioRender.com.)

CANNABIS AND EXERCISE: THE EVIDENCE

Acute Cannabis Administration

Interest in understanding the interactions of cannabis use and exercise is not new. However, most early investigations approached the topic to understand exercise safety and not performance, with studies commonly employing clinical populations. Perhaps surprisingly, since these early investigations, performed 3 to 4 decades ago, relatively little novel research has been undertaken in this area, owing largely to the noted research barriers and perhaps little motivation to study a drug that was almost universally illegal and banned in competition. As a result, much of the evidence cited here for and against the use of cannabis in conjunction with exercise is based on studies using non-athletic populations, having consumed cannabis that may differ significantly in cannabinoid concentrations compared with today's standard, and making measurements using techniques that are now considered rudimentary. While the seminal exercise and cannabis studies have a strong scientific foundation, the context in which they were designed and carried out limits their applicability in answering questions about sport performance in athletes. As a result, the evidence regarding cannabis and THC use with exercise is conspicuously sparse compared with the empirical data available for other performance-related drugs and supplements.

Cardiovascular Effects. Two of the original studies performed on cannabis and exercise demonstrated that cycling time to the onset of angina was shortened in men with advanced coronary artery disease (Aronow & Cassidy, 1974; 1975). While a decrease in exercise capacity is an important finding, it is noteworthy that angina is not typically a limiting concern for most competitive athletes, nor even the average exerciser. However, it does suggest that cannabis could interfere with the myocardial oxygen supply-demand relationship, which could impinge on cardiac function, even if only in those with compromised coronary flow. Notably, both of these early studies used smoking as a means of cannabis administration, and the inhalation of carbon monoxide itself may have exacerbated this effect.

Two additional studies in healthy individuals demonstrated that cannabis led to an elevation of heart rate during submaximal intensity exercise (Avakian et al., 1979; Steadward & Singh, 1975). As was common at the time, these studies used submaximal heart rate responses, or work output at a given submaximal heart rate, to predict exercise capacity and consequently concluded that cannabis reduced performance. This message that cannabis is, therefore, ergolytic (performance inhibiting) has since been commonly repeated and is incorporated in a number of systematic reviews that also arrived at this conclusion (Campos et al., 2003; Docter et al., 2020; Huestis, 2002; Pesta et al., 2013). While it might be true that a reduced heart rate and cardiac output would be expected to decrease maximal exercise performance, this logic assumes that there is no compensatory change in stroke volume and that the inflation of rate is sustained with increasing exercise intensity (i.e., a consistent linear relation between heart rate and oxygen uptake (VO_2)). However, the only study that measured maximal exercise performance following cannabis consumption demonstrated this to be untrue, as VO_2 lines converged with increasing exercise intensity and heart rate at intensities > 80% of max effort were similar between cannabis and control conditions (Figure 2A). Further, there were no reported differences in maximal heart rate, minute ventilation, or VO_2 (Renaud & Cormier, 1986). Notably, there are many examples of other definitively ergogenic substances that increase submaximal heart rate and yet still improve exercise performance, such as caffeine and ephedrine (Bell et al., 2000; 2001). This study did, however, report a decrease in maximal exercise time (Figure 2B), but it is worth noting that this difference represented no more than a single, 1-minute stage workload (16.4 W increase), and thus the practical implications are somewhat unclear (Renaud & Cormier, 1986).

Respiratory Effects. As was noted previously, cannabis has been shown to have a bronchodilator effect at rest, and it is reasonable to hypothesize that bronchodilation may also occur during exercise given that pulmonary function is maintained post-exercise (Renaud & Cormier, 1986). While ventilation is not commonly considered a primary limitation to maximal exercise in non-elite athletes (Saltin & Calbet, 2006), altering the work of breathing could reduce the volume of blood diverted from locomotor muscles to respiratory muscles, particularly for those who experience flow limitations (Guenette et al., 2007; Sheel et al., 2018). Such effects would be expected to be accentuated with exercise for those with diagnosed flow limitations, such as persons with chronic obstructive pulmonary disease (COPD). This was recently explored by Abdallah et al. (2018), who examined the impact of inhaling vaporized cannabis prior to symptom-limited cardiopulmonary exercise testing. Even among these advanced COPD patients, breathlessness was not shown to be improved during exercise, and no effect was apparent on any cardiorespiratory responses or exercise time, which was typically less than 5 minutes (Abdallah et al., 2018). Specific investigations of the respiratory effects of cannabis consumption prior to or during intense exercise have yet to be performed in healthy athletes. Perhaps counterintuitively, in opposition to the well-known adverse effects that tobacco smoking has on pulmonary function, there is little evidence suggesting similar effects among non-heavy cannabis users (Pletcher et al., 2012). Thus, even with occasional or low cumulative cannabis use outside of the sporting environment, it seems unlikely that performance would be affected by persistent alterations in lung function that could impede cardiorespiratory function.

Strength Effects. To date, only one study has offered even a superficial consideration of the effects of cannabis use on measures of strength, with none having considered muscular endurance, power, or anaerobic capacity. Handgrip strength was compared before and after smoking cannabis, and Steadward & Singh (1975) concluded that no effects of cannabis use were apparent on strength. Additional

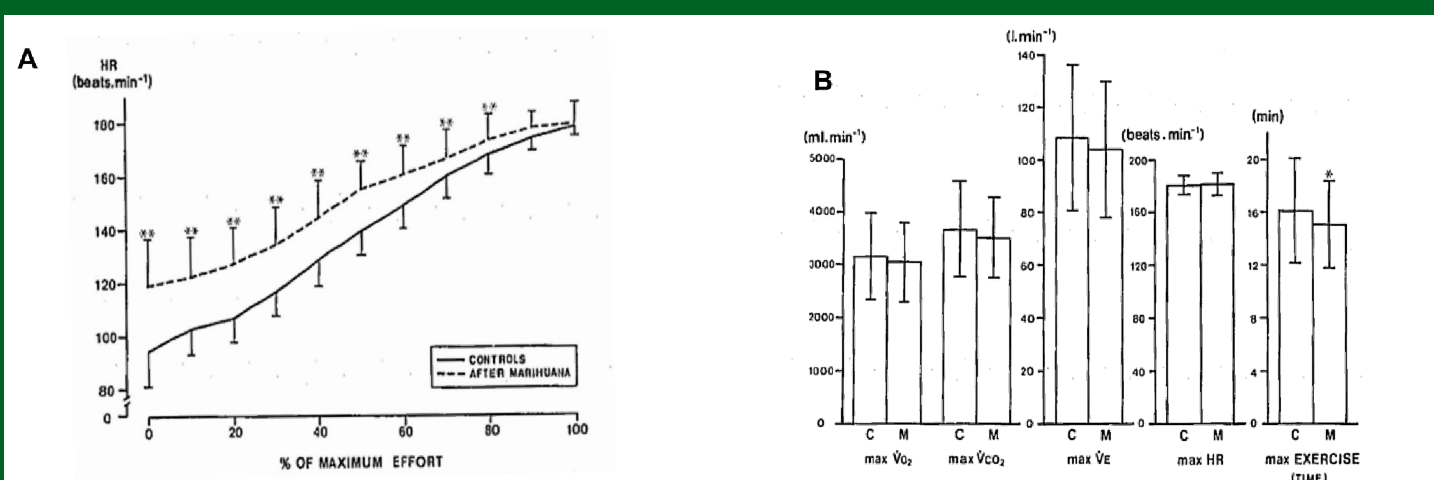

Figure 2: A. The heart rate (HR) response to increasingly intense exercise, with and without cannabis (marijuana) administration. B. Maximal values for oxygen consumption (VO_2), carbon dioxide production (VCO_2), ventilation (VE), heart rate (HR), and exercise time with (M) and without (C) administration of cannabis prior to exercise. Data are mean ± SD. L, liters. (Reproduced from Renaud and Cormier, 1986 with permission.)

investigations examining cannabis use and muscle strength are needed before conclusions can be made.

Chronic Cannabis Use

The impact of cannabis use on athletic performance may not be limited solely to the immediate effects, and it is of interest to athletes and practitioners to understand the potential effects of out-of-competition use as well. Of the existing data, there are no reported differences between cannabis users and nonusers with respect to performance-related outcomes, including VO_2max, muscular strength, endurance, work capacity, or perceived exertion (Lisano et al., 2019; Maksud & Baron, 1980; Wade et al., 2021). In physically active cannabis users, there were also no differences in anaerobic power, nor measures of stress and inflammation (Lisano et al., 2019; 2020). Longitudinal studies and studies specifically using athletic populations have yet to be performed and would offer important insight.

KNOWLEDGE GAPS

There is much we currently do not know about both the immediate and long-term effects of cannabis use on exercise performance. Specifically, we lack targeted studies that have used athletic populations and employed contemporary performance tests up to and including maximal intensity exercise. The vast majority of the existing exercise data has been generated using submaximal cycle ergometry, and insight into other modes of exercise, using both aerobic and anaerobic energy production systems, is necessary. Further, the impacts on strength, power, and muscular endurance need to be studied, as well as the physiological and cognitive demands across a variety of sports, including team sports. Finally, the effects of different modes of cannabis administration, cannabinoid concentration, and timing need to be considered using a diverse population, including both males and females. The psychotropic effects of THC on ratings of perceived exertion, nociception, fatigue, and pacing strategies are also deserving of attention. Further understanding of the effects of cannabis on the cardiorespiratory system and both short- and long-term effects on general health are necessary to assess the safety of cannabis use in conjunction with exercise.

PRACTICAL APPLICATIONS

- Whole cannabis and THC have been shown to alter cardiovascular function at rest and during submaximal exercise, most typically by increasing heart rate. As such, predictions of maximal exercise performance and response may inaccurately reflect demand at submaximal intensities. Some cardiovascular effects, including the work of the heart (rate pressure product) may also be affected by THC, other cannabinoids, hydrocarbons, and carbon monoxide.
- Differing methods of cannabis consumption, and the use of natural or derivative products, can have meaningful effects on cannabinoid uptake, pharmacodynamics, pharmacokinetics, and the resultant physiological responses.
- The use of cannabis containing THC in-competition remains prohibited in most sports, specifically those governed by the World Anti-Doping Agency rules. Cannabis use in conjunction with sport and exercise, or recreational use peripheral to competition, could result in a doping infraction.
- The full effects of cannabis use on athletes are incompletely understood, including the impact whole cannabis and THC may have on maximal exercise performance, and both short- and long-term safety. Until such evidence is available, cannabis in conjunction with exercise should be used with caution.

SUMMARY

Cannabis use in society is prevalent, and there is potential for further adoption as recreational and medicinal use becomes legal and increasingly accessible in many parts of the world. There is evidence that cannabis is already widely used by certain segments of the athlete population, both with the intention of gaining a competitive advantage and outside the sporting environment. However, both the short- and long-term effects of use have not been rigorously investigated using contemporary techniques and methodologies. While the exercise literature is clearly limited, current evidence demonstrates that cannabis affects both the cardiovascular and respiratory systems, and it is possible that these alterations could be consequential to exercise performance and safety. While not particularly relevant to athletic performance modeling, evidence from clinical populations highlights potential mechanistic pathways through which cannabis use may affect physiological function. The limited available work examining the effects of long-term cannabis use does not indicate that chronic cannabis consumption necessarily depresses exercise performance. Robust, specifically designed studies examining the acute and chronic effects of cannabis consumption in athletic populations and utilizing diverse exercise tests are needed to comprehensively understand the interactions between cannabis and the ability to perform exercise.

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