CHAPTER FIVE

Recreational Marijuana Use and Its Effects on Cognitive Skills in Adolescents

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According to the United Nations Office on Drugs and Crime (UNODC, 2021), among the most consumed drugs of abuse in the world, marijuana (cannabis) is the one most often used for recreational purposes. The UNODC estimated there were about 200 million nonmedical marijuana users in 2019, as the most socially accepted and popular drug of abuse in most countries (UNODC, 2019). For UNODC (2019), this would be reflected in the significant increase of people undergoing treatment for disorders related to cannabis use as its principal drug of abuse.

Their latest report (UNODC, 2021) covered the first period of the Covid-19 pandemic and found that many countries around the world reported increased cannabis use during this time. Indeed, in a survey of health professionals from 77 countries, 42% stated marijuana use had increased. These trends, however, seem to have originated before the beginning of the pandemic. Data from the Organization of American States and the Inter-American Drug Abuse Control Commission (OAS-CICAD, 2019) show the prevalence of cannabis use within the past year had increased among high school students by 2019, mainly in countries with changing regulations on marijuana use.

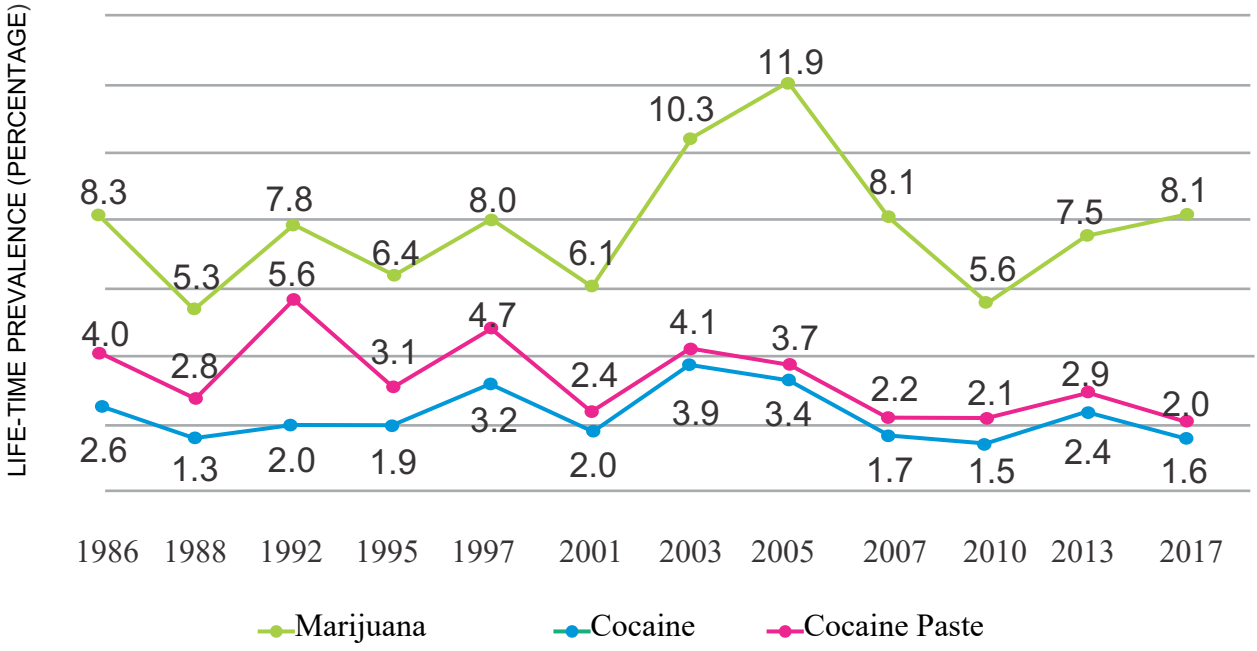
Among young Americans, cannabis use held somewhat stable at around 20% between 2008 and 2016, with some fluctuations. While there is no reliable data on trends in Canada, it has been reported that use among young people 12 to17 increased by more than 15%.

The same report from OAS-CICAD (2019), describes significant increases in cannabis use in South America. Chile experienced an increase from 15% prevalence in 2009 to almost 35% in 2015. In Uruguay, 13% in 2011 became 17% in 2014. In Colombia, the rate doubled from 11% to 21%, while in Ecuador, it tripled from 4% to 12%. Peru and Bolivia meanwhile reported modest increases of about 5% between 2009 and 2016.

In Peru, the Information and Education Centre for the Prevention of Drug Abuse (CEDRO, 2017) reported that trends in cocaine use had relatively stable prevalence rates (annual, quarterly, monthly) in the years before the pandemic, and lower than most other South American nations. However, in the case of marijuana, there has been a steady increase in the prevalence of the life-time consumption in the Peruvian population since 2010 (Figure 1).

Figure 1

*Trends of Illicit Drug Use in Peru (*Cedro (2017)



Regarding the problematic marijuana use in school students, the National Commission for

Development and a Drug-free Lifestyle (DEVIDA, 2017) assessed rates of use in the past 12 months in Peru, finding more than half had used cannabis alone and before mid-day. These patterns of use are usually associated with more frequent consumption, symptoms associated with dependence and low academic achievement, according to findings by Scopetta, Pérez and Muñoz (2013) in Colombia. About half of the high school students reporting alcohol and marijuana use in the last year show indications of problematic consumption (DEVIDA, 2017). Importantly, approximately 3 in 10 students who reported marijuana use in the last year admitted having memory problems and problems controlling their rate of consumption.

The Covid-19 pandemic has changed the way people relate to drugs, from access to consumption. This has strongly impacted on public health, as use of alcohol, tobacco, cannabis, and other substances have increased due to the imposition of new lifestyle patterns like teleworking, unemployment, and quarantine, as well as psychological issues like deficits in stress management, increased anxiety, and financial problems.

The University of Valencia (2021) released a report on trends in consumption in Latin America in the context of the pandemic that found an striking increase in marijuana use. Colombia was ranked first in South America, with 62.5% of the consumer population showing signs of problematic cannabis use, followed by Peru with 28.6% and Ecuador with 14.8%. These results are consistent with those of contemporary UNODC (2021) report showing how the use of cannabis (as well as sedatives) has increased in many countries during the pandemic.

Risks of Cannabis Legalization

In Latin America, eight countries have approved the legal use of marijuana for medical purposes (Argentina, Colombia, Ecuador, Chile, Paraguay, Peru, Mexico and Uruguay), but only

two of these, Uruguay and Mexico, have gone further and legalized it for recreational purposes. Uruguay was the first country in the world to do so in 2011, and Mexico approved recreational use and personal production in 2021.

Regarding this, some experts have argued that cumulative experience with how tobacco and alcohol use respond to regulations suggests the legalization of marijuana—even for only medical purposes—could be causing groups of young people and adults to perceive lower risk, and a corresponding process of normalization of cannabis use in these groups.

According to the report of the International Narcotics Control Board (INCB, 2018), marijuana use has increased among adults over age 21 in jurisdictions where medical use has been approved It also reports higher rates of daily consumption and more requests for treatment of cannabis dependence cases.

Many researchers and experts no longer consider marijuana a soft drug because the higher concentration of THC and consequent potency, and reports of behaviours associated with early-onset schizophrenia and other psychopathological comorbidities in young consumers (Cardeilla, 2006; Ruíz, 2019; Smith et al., 2003). As a consequence of this, with the additional trend towards full legalization for recreational purposes, we predict demand will increase, mainly young people, and consumption trends will continue to rise in tandem with mental health problems related to cannabis abuse and dependence.

The aforementioned studies notwithstanding, we still lack clear evidence of the impact permissive laws are having on marijuana use. What can be seen is that these laws have not reached the objectives for which they were passed, such as the elimination of drug trafficking and the black market, less consumption in adolescents, regulations to prevent cannabis products from containing other substances, and the provision of economic benefits to states. On the contrary, there is

evidence (e.g., Dilley et al. 2021) suggesting sanctioned commercialization of cannabis-derived products may have increased use among children and adolescents, as these trends are increasing, as are requests for cannabis abuse treatments for adolescents.

According to the National Service for the Prevention and Rehabilitation of Drug and Alcohol Consumption of Chile (SENDA, 2021), it is necessary to continue assessing the outcomes of these laws multidimensionally with a long term view, based on the best available evidence, according to the characteristics, needs, and consumer patterns of each population and national or regional reality.

Cognitive Effects of Cannabis Use in Adolescents

Cognition refers to the capacity for reasoning and thinking, including the ability to comprehend, remember, organize, and appropriately manage information received by the senses. Cognitive functions if importance here include attention, concentration, memory, problem-solving skills, perception, and action.

Marijuana use can cause cognitive changes in two ways: (1) after acute but heavy use due to high concentrations of cannabinoids in the central nervous system, and (2) as a result of chronic use, due to the constant maintained exposure of the nervous system to cannabinoids. Although the acute cognitive effects of cannabis are reversible and widely documented, the debate continues over the degree to which the effects of chronic use can be fully recovered from after discontinuing use.

The main acute effects of cannabis are sensations of well-being and euphoria, relaxation, unmotivated laugher, talkativeness, slowness, slight changes in perceptions of colour , sounds, and touch—including hallucinations in some cases—as well as sedation and induced sleep.

Physiological effects include increased heart rate, lower blood pressure, dizziness, motor instability, and increased appetite.

As for the long-term effects, the UNODC report (2018) notes habitual consumers of marijuana are vulnerable sensitive to dependence, with 1 in 10 developing a dependence at some point in their life. For adolescents, this ratio is 1 out of 6, and this rises to 1 in 3 for those who consume it daily. The report also highlights significant evidence showing regular and intensive use during adolescence to associate with more severe and persistent negative outcomes than use in adulthood, as well as less capacity to recover if use is ceased. However, most of this research comes from studies on animals, so this is not conclusive in relation to humans. But there has been one landmark longitudinal study (Meier

et al., 2012), which followed a cohort of over 1,200 for 35 years, finding that "intensive" marijuana smokers who started using it around age 14 presented irreversible cognitive damage at the cognitive level, including the loss of up to eight points of IQ.

According to many authors (Beverido, 2010; Cuenca-Arroyo et al., 2013; Parolaro, 2010; OPS-OMS, 2018; Volkow et al., 2014), it is important when examining the impact of marijuana use in mental health to remember that people with substance dependence often have other associated mental disorders. There are clinical studies showing a strong relationship between cannabis use and increased risk of schizophrenia, depression and anxiety (OPS-OMS, 2018).

In this context, Rodríguez-Jiménez et al. (2007) conclude that early, intensive and prolonged cannabis use increases risk of developing a schizophrenia in genetically predisposed people, particularly when also predisposed to cannabis dependence. The first psychotic episode might appear after just one year of use, or even faster if the onset is before age 18. In the context of pharmacological treatment, this group would have a worse response in the therapeutic process

with medications and would tend to relapse more often in the next 15 years compared to non-using schizophrenics.

This data is related to a longitudinal New Zealand study by Fergusson et al. (2003b) on cannabis dependence and psychotic symptoms at 18 and 21 years of age. They established an association between cannabis dependence and risk of psychosis at the ages of 18 years (3.7 times greater risk) and 21 years (2.3 times greater risk), maintaining this association at age 25. Later, the National Academies of Sciences, Engineering, and Medicine (2017) conducted an in-depth review of more than 10,000 studies on the health effects of cannabis and cannabinoids, finding substantial evidence of an association between marijuana use and developing schizophrenia or other psychoses, with higher frequency of use leading to greater risk.

Neuroscientific evidence that the prefrontal cortex continues to mature through the course of adolescence, which is an area responsible for evaluating situations, judgement and decision-making, planning, maintaining emotions and self-control. According to the National Institute on Drug Abuse (2020), although young people often live with a sense of invulnerability, in truth their ability to assess risks and make sensible decisions is limited. Batalla et al. (2013) carried out a systematic review of controlled neuroimaging studies of chronic cannabis use published up to 2012 in the EMBASE, Medline, PubMed and LILACS databases. The authors concluded that chronic marijuana use can alter brain structure and function for both adults and adolescents.

These studies indicate that use and abuse of cannabis (or alcohol) interferes with some brain functions and areas related to self-control, learning, motivation, and memory. In this vein, Meier et al. (2012), Gruber et al. (2012), Zalesky et al. (2012), Iversen (2003), and Melchior et al. (2017), have found the brain maturation process to be hindered by cannabis use in adolescents, exposing them to potentially severe consequences in the short, medium and long-term.

Drugs of abuse such as marijuana can activate certain neurons because their chemical functioning mimics naturally-occurring neurotransmitters that have affinity for them. But although emulating chemical functions of these neurotransmitters, they behave differently and cause abnormal messages to be transmitted through neural networks.

According to Farré and Abanades (2007), marijuana use can cause cognitive changes in two ways: (1) after acute consumption due to high concentration of cannabinoids in the central nervous system, and (2) after chronic use due to the prolonged presence of cannabinoids in the nervous system. While the acute cognitive effects tend to be reversible, controversy continues as to whether the chronic cognitive effects can be recovered from after discontinuation.

Regarding the effects of the recreational cannabis use on adolescent mental health and cognition, there is evidence that the impact of its main psychoactive component, delta-9-tetrahydrocannabinol (Δ9-THC), poses significant risks for the adolescent brain (Farré et al., 2006; PAHO-WHO, 2018; Volkow, 2014). In an fMRI imaging study with 16 chronic cannabis users and 16 control participants, Hester et al. (2009) found that users showed less activity in the anterior cingulate cortex, which governs error detection. The authors suggest this could limit consumers' ability to control their behaviour with precision, which could help to explain the lack of awareness of their addiction as it forms, allowing it to propagate and become chronic. This relates to the arguments of Inozemtseva and Matute (2013) that cognitive functions are key to understanding the development of addictive behaviour—, that is, the transition process from recreational substance use to dependence.

Research in this area has established inconclusive but important relationships between marijuana abuse and cognitive impairments in executive functions such as planning, problem solving, decision-making, and control of emotions and behaviour. As such, frequent cannabis use

affects cognitive functions at various levels, from basic motor coordination to more complex executive functions (Auer et al., 2016; Crean et al., 2011; PAHO-WHO, 2018; Garavan & Hester, 2007; Hanson et al., 2010; Ranganathan & D'Souza, 2006). These deficits differ depending on the severity of consumption, age of onset, and time of consumption. It has also been suggested people with deficits in executive functions from cannabis use have difficulties learning the skills necessary for recovery, and are more vulnerable to relapse.

Gruber et al. (2012), worked with 34 heavy and chronic cannabis smokers distributed into two groups, those with an early onset and those with a late onset (16 years as a cut point), as well as a control group of 28 non-consumers. On a battery of neurocognitive tests, smokers performed poorer than controls in executive functions. When taking age of onset as a point of comparison, the contrast with the control group was more noticeable in the early-onset group, who smoked twice as often and almost three times more per week than late-onset smokers did. This suggests the age of onset, frequency, and intensity of smoking affected cognition more in those who had early consumption. Early-onset use also correlated with poorer cognitive function, and with greater frequency and intensity of smoking. The authors argue that cannabis use in the neurodevelopmentally vulnerable phase of adolescence significantly increases the risk of impairing cognitive function and causing permanent neuropsychological changes.

In this regard, Fergusson et al. (2003) conducted a 25-year longitudinal study with 1,265 children of New Zealand, evaluated at age 16, 18 and 21. They found that cannabis use was associated with increased risk of dropping out of school, and a lower chance of attending and graduating university, supporting the opinion that frequent cannabis use can be detrimental to educational achievement in young people. However, in contrast with other studies, they argue that it is likely this result reflects the effects of the social context in which marijuana is used, rather

than any direct neuropsychological effects on cognitive ability or motivation.

One of the most comprehensive publications on the subject of cognition and cannabis use is the aforementioned longitudinal study by Meier et al. (2012) in New Zealand. They assessed changes in IQ at age 13 (before any drug use) and again at age 38 and found that those with early and persistent cannabis use lost an average of 8 IQ points in contrast to non-consumers and non-persistent consumers. Auer et al. (2016) obtained similar results in the United States, finding a consistent relationship between verbal memory deficits and heavy cannabis use throughout adult life—however they did not find negative impact on other areas of cognitive function.

A recent review of 38 longitudinal neuroimaging, neurophysiology, and neuropsychological studies by Debenham et al. (2021) examined the impact of cannabis and other substances on the nervous system and the recoverability of young brains (from 10 to 25 years) after damage caused by polysubstance use. They found substance use to cause functional, structural, and cognitive deficits, with the severity of damage associated with frequency and intensity of use.

If we try to reason globally about what has been discussed so far, we can say there is more information, knowledge, and empirical evidence today on the adverse effects of marijuana on mental health and on the cognitions of adolescents than ever before. The two New Zealand birth cohort studies by Meier et al. (2012) and Fergusson et al. (2003a) stand out as having strong methodology, design, and scientific rigor. They also benefited from the context that participants lived in a period when marijuana use was a common behaviour in adolescence and adulthood, so a sizeable number of them had smoked frequently and for long periods, providing quality information of the effects of habitual and prolonged use.

Results of the New Zealand studies coincide with others of similar design by Wittchen et

al. (2007), Van Os et al. (2002), and Swift et al. (2008) in Europe and Australia. For example, Van Os et al. (2002) evaluated over 4 thousand Dutch people in 1996, 1997 and 1999, and found cannabis users to have a threefold increased risk of psychotic symptoms at follow-up—and up to 6.8 times higher risk for heavy users.

Studies in Latin America

Research carried out in Latin America has obtained similar results regarding the association between marijuana use and negative effects on cognitive function in adolescents. There is sufficient evidence to show early marijuana use (age 13 to 15) causes disorders in cognitive functions, particularly attention and memory. These deficiencies result from chronic consumption and can become permanent with frequent and intense use. Age of onset would therefore be a prognostic marker of the neurocognitive damage; however, those with spaced consumption and moderate dosage and frequency tend to recover their attention and memory abilities after stopping consumption.

Mena et al. (2013) developed a study with a sample of adolescents from four schools in Santiago, Chile. They formed two groups: 40 users of exclusively marijuana (no other substances) and 40 non-users. Neuropsychological tests and NeuroSPECT results were compared with a database containing people considered normal equivalent to the study group. Users showed poorer cognitive abilities related to learning such as attention, concentration, prioritization, visuospatial integration, immediate retention, and visual memory.

A Peruvian study by Fiestas and Torres (2012) compiled the most solid findings on marijuana use and cognition. The authors focused on memory, attention, emotion, and decision making because they are neuropsychological functions commonly reported to associate with

frequent cannabis use. They found well-documented evidence that cannabinoids negatively affect short-term memory, decision-making, attention temporarily, and the interaction between cognitive events and emotion.

In Ecuador, Pozo-Hernández et al. (2019) analyzed the influence of marijuana use attention, memory, and executive functions in a group of 16 young habitual recreational users (Male $n = 8$, Female $n = 8$; $M_{age} = 23.38$, $SD = 1.78$), compared to a group of 16 young non-users (Male $n = 8$, Female $n = 8$; $M_{age} = 22.25$, $SD = 1.92$). The results show that the regular, recreational and intense-habitual use of marijuana impairs selective attention, short and long-term memory, working memory, planning, mental flexibility, and inhibitory control in young people.

In Chile, Goycochea et al. (2020) conducted a review of studies on the association between visuospatial processing and marijuana use (not dependence) in high school students. They included three types of correlational studies: comparisons of declines between visuospatial processing and other cognitive tasks; comparisons of cognitive effects between high school students and adults; and large samples, longitudinal studies, including twin studies, all controlled for with abstinent participants. They concluded that cannabis use can moderately affect visuospatial processing and learning in students, even when they are not addicted— though but these functions could recover with abstinence and tend to be less affected than others are.

Finally, it is also important to mention some review studies pointing in the opposite direction: For example, a meta-analysis by Scott et al. (2018) found only weak associations between marijuana use and cognitive functioning in cross-sectional studies of adolescents and young people. They highlight 72 hours of abstinence from use remedies deficits related to cannabis use, citing several studies that may have exaggerated the magnitude and persistence of these deficits.

While a negative impact on the cognition of adolescents from intense cannabis use is well documented, the evidence is not conclusive because most studies involved multiple drugs, limiting the ability to infer a direct link between cannabis and cognition in a vacuum. Few studies have tried to control for exclusive marijuana use in their participants to isolate it from any effects from other drugs.

Use Patterns and Risks of Cannabis Potency

It is not easy to establish a clear profile of cannabis users. The World Health Organization (1994) suggests the follow categories of use patterns. These include (A) Experimental consumers, who try it once or use very infrequently/inconsistently; (B) Social/moderate consumers who only partake in recreational and social contexts with others; and (C) Risk consumers with recurrent habitual use and negative impacts on their life obligations, physical health (e.g., increased hearth rate, memory problems), and mental health (e.g., anxiety, altered consciousness). The first two categories are distinct from the third in that they do not describe problematic use and are low-risk. Risk consumers are more widely exposed to various harmful effects of consumption, including cognitive problems.

For Cohen and Sas (1998) and Gamella (2003), the patterns and trends of cannabis use have a wide range of characteristics. They argue that it is closer to alcohol use than other drugs of abuse. Some consume it experimentally once or a few times and never do again, and others use it sporadically for years but eventually drop it— but another type of user easily increases their frequency and dosage and tend to use other drugs concomitantly.

Depending on various internal factors (medical and psychopathological comorbidities), as well as external and contextual ones, there are those who easily develop problematic and intense

use. We will now take a tangential look at these patterns of consumption that describe many young people who started marijuana use early on.

Intense marijuana use includes recurrent and increasing smoking, increased dosage, and heightening of the circumstances and reasons for their use. It is about daily usage, although there may be two levels: moderate use and daily-intensive use. The moderate consumer tries to control their consumption. Many do it preferably on weekends and in the context of multiple drug use in social situations. Daily consumers, however, do so with certain controls given by the family or the environment, others limit it to leisure time, rest or at night alone—also often accompanied by other drug use. Regarding this, Swift et al. (2012) found a correlation between the intensity and frequency of cannabis use and the progression to multiple drug use. Daily intense users are also at an increased risk of personal and socio-family problems.

Worldwide, various factors have been shaping the rise in cases of marijuana abuse and dependence. One might be the new qualities and varieties of cannabis, including increased in the potency of the drug. The European Monitoring Centre for Drugs and Drug Addiction (EMCDDA, 2004) suggests that potency is one of the factors to calculate the dose during a period of time of consumption, however, other factors must be considered that could be more important when evaluating the characteristics of consumption exposures, such as smoking technique, route of administration, dose, intensity of consume, and mental health status at the time of use. The authors point out that t high potency marijuana has always been available, and the difference today is the larger variety.

In the UK, Hardwick and King (2008) report a study on confiscated cannabis herb and resin sample. They found a mean THC (potency) concentration of the seedless samples of 16.2% (range = 4.1 to 46%), and a mean potency of 15.0% (with seeds), close to reported values by others

in recent years.

In Colombia, Florian et al. (2008) carried out a study analyzing cannabinoid content in samples of illegally cultivated Cannabis sativa. While cannabinoid THC predominated all samples, those from the Eastern Plains had a THC concentration of over 15%, those from the Cauca region had over 10%, and those from the Santa Marta and Coffee regions had 3% and under 2% respectively. The authors argue this indicates a variety of improved marijuana strains are being cultivated in the country.

Recent years have seen reports of increasing use of so-called "Cripy" marijuana. This is a variety created through genetic manipulation to boost THC concentration. Also known as hydroponic or organic marijuana, it is one of the most harmful since it is not exposed to natural sunlight during its growth, with artificial light used instead, overloading it with more THC (Granados & Riaño, 2015). This variety has had a great impact on traffic and use in countries of the region including Chile, Peru, and Colombia.

These results are related to those reported by Mehmedit et al. (2010), after carrying out the cannabis monitoring for the Potency Monitoring program of Mississippi University's National Institute on Drug Abuse., which provides data on the potency of marijuana confiscated in the United States during the period between 1993 and 2008. The authors found an increase in the average THC content for all cannabis preparations from 3.4% to 8.8%. While they found no increase in potency for hashish between '93 and '03, the average annual potency varied from 2.5% to 9.2%, and then from 2004 to 2008 it spiked from 12% to 29.3%. The researchers argue the increase in potency came from non-domestic samples. In this regard, Freeman and Winstock (2015) evaluated the consumption of high and low potency cannabis in a population of adults, attempting to establish an association between frequency, dependence, and concerns about use.

High-potency cannabis was found to be associated with greater severity of dependence in young people, highlighting the impact on memory.

This topic still requires further research since it is not clear whether potency has become a powerful risk factor directly linked to cognitive deficits, the continuation and exacerbation of consume, and the severity of dependency. Nonetheless, the reviewed evidence suggests early, intensive, and chronic use of cannabis facilitates or precipitates the development of mental health problems, including deficits in cognition like memory, attention, and executive functions. These indications should be considered in future research, as well as for updating or designing prevention and early detection programs for adolescent marijuana users.

Conclusions

Marijuana use trends in countries where therapeutic use has been legalized have increased. In Peru, there was already a slight increase before the COVID-19 pandemic, but still lower than other countries in the region. The prevalence of consumption after the onset of the pandemic increased by 28.6%. Unfortunately, there are no recent national studies that corroborate this consumption trend.

Temporal neuropsychological effects of marijuana include deficits in a wide variety of cognitive functions, including processing speed, attention, temporal perception, memory, and executive control. The most well-established deterioration is related to memory processes. In adolescents, even considering that the effects of using marijuana are mediated by the frequency, THC potency, duration of use and other factors, use that begins in this period of development could lead to age-related cognitive decline.

While not conclusive, there is also evidence of risks in terms of the onset of psychosis and

severity of the symptoms, cognitive performance, and general functionality—especially in consumers who are biologically vulnerable and have prolonged use with large doses over time. There is moderate evidence that adolescent users with poorer cognitive functioning are more likely to become regular cannabis users.

Neuroimaging studies have found relationships between frequency and duration of use and both structural and functional changes in brain regions involved in memory and cognition. This corresponds with findings that marijuana smokers tend to show lower performance in tasks related to working memory, verbal fluency, and executive function compared to non-users.

There is inconclusive evidence that attention and memory are frequently impaired even in healthy cannabis users. Executive functions like decision-making, risk evaluation and impulsivity/inhibition, are diminished in most assessed consumers. Under the acute effects, working memory is hindered but remains within normality in groups with medium and long-term consumption—and verbal fluency in acute use does not seem altered. Finally, it is necessary to continue longitudinal studies that can clarify the influence of cannabis use on cognitive performance in adolescents.

Regarding the potency of cannabis, some studies coincide in finding a higher concentration of THC in hybrid varieties. While the potency of the herb has apparently remained stable, the modified varieties have reportedly increased— mostly indoor, hydroponic genetically modified crops. However, more research is still needed to continue exploring the relationship between cannabis potency and the impact on adolescent cognition.

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