

## **An Updated Review of the Research on the Risks and Harms Associated to the Use of Marijuana**

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### **Introduction**

Currently and in recent years, there is a continued debate over the personal use of marijuana in North America and around the world. The debate remains adversarial and is receiving a large amount of public attention in various media. It is commonplace for former supporters of the existing drug control policies to publicly announce their changes of opinion. In British Columbia, several former Attorneys General joined a growing number of activists looking for decriminalization and legalization (Mulgrew, 2012). In early 2012, the former US District Attorney, John McKay, who prosecuted Marc Emery, a Canadian, for selling marijuana seeds to American residents, has publicly denounced prohibition policies (CBC News, 2012). At the same time, the focus of the marijuana debate continues to be dominated by arguments about how prohibition does nothing more than put money into the pockets of organized crime, punish otherwise law abiding citizens, violate people's right to put whatever they want into their bodies, and throw good tax dollars after bad on a failed war on drugs (Harris, 2012). Decriminalization or legalization of marijuana, the advocates commonly argue, is really the only sensible solution.

What seems to have become increasingly lost in the debate over the personal use of marijuana, however, is a consideration of the negative effects that marijuana can have on users and how those harms can be addressed within any policy direction. It seems that we have moved past debating

whether the use of marijuana is potentially harmful enough to merit concern, to, it is not. In our view, though, such an assumption is premature. Indeed, as we established in a previous review of the literature (Diplock, Cohen, & Plecas, 2009), marijuana should not be viewed as a benign substance, but rather as one that, though unlikely to pose serious harm for most, will negatively affect a proportion of users. With that in mind, and in the interest of considering even more recent literature, the purpose of this current review is to update the original report on the harms associated with marijuana use. It is the hope of the authors that this information will begin to play a more prominent role in the discussions about future marijuana control policies. Similar positions have been put forward by authors in other parts of the world (for example see Roxburgh et al., 2010).

Research on the effects of marijuana and the cannabinoids on the various functions within the human body is growing rapidly. Since the original review (Diplock et al., 2009) focusing on research between 2000 and 2007, a greater number of researchers have focused on the potential for marijuana to be used medicinally to alleviate a number of negative health conditions (Leung, 2011). Furthermore, research on the biological mechanisms of marijuana's active constituents has also increased, particularly to help scientists determine how to best take advantage of the therapeutic benefits of the drug while avoiding the negative effects (Bifulco, 2009). No longer is the focus of research simply on asking how marijuana can negatively affect users. However, while these are valuable areas of research and their contributions will help us to better understand marijuana as a form of medicine, this type of research will largely be outside the scope of this review. This review, a synthesis of the best evidence from over ten years of research between 2000 and 2012, will add the most current research on the potential harms associated with marijuana use to the information presented in the original review. Of course, just as the body of knowledge has changed in the years since the previous review, it is also likely that future years will provide an even greater level of clarity around the true extent of harms. Just because research in one or more areas might not currently identify likely risks or harms, one should not interpret this as demonstrative evidence that no harm exists. It is the nature of research, for future

studies to build and improve upon the methodologies and results of past research, and therefore uncover things that were once unknown.

It is especially important to be mindful of the most current research on marijuana use because of the changing nature of both academic research and the drug itself. In other words, not only do methods for studying the effects of marijuana change and improve over time, but we must also be aware that marijuana may also be changing. The term “marijuana” does not refer to cannabis with a particular level of  $\Delta^9$ -Tetrahydrocannabinol (THC). Over time, the level of THC in marijuana has changed; typically, it has increased. However, because there have been very few studies on the changes in potency of marijuana over the years, it cannot be confirmed conclusively that marijuana users in the 1970s were typically consuming a different drug than today’s users. However, the information that does exist suggests that, on average, marijuana users today are exposed to higher levels of THC than in past decades. Research on potency trends of seized marijuana between 1980 and 1997 concluded that average THC levels of marijuana seized in the United States increased in levels of THC from less than 1.5% in 1980 to approximately 3% in the early 1990s, to over 4% in 1997 (ElSohly, Ross, Mehmedic, Arafat, Yi, & Banahan, 2000). By 2008, the average THC level of seized marijuana was over 11% (Mehmedic et al., 2010). While not observing large substantial increases in potency, McLaren, Swift, Dillon, and Allsop (2008) reported increasing trends in the United States, the United Kingdom, the Netherlands, and Italy. In Canada, the Royal Canadian Mounted Police [RCMP] (2008) reported that seizures of marijuana, in which only the buds are tested, had an average THC concentration of around 11% in 2008. Seizures in Europe of imported “herbal marijuana” typically had THC levels between 2% and 8%, but the potency of hydroponically-grown marijuana may be as high as double that (King, Carpentier, & Griffiths, 2005). Potter, Clark, and Brown (2008) found the median THC level from 2004 and 2005 samples of this more potent indoor-grown marijuana to be 13.9%. Common among all of the studies was that there was a high degree of variability, so it must be kept in mind that a regular user would likely be exposed to marijuana of various different concentration levels of THC. As the majority of marijuana production remains the industry of

criminals, many of whom use hydroponic operations and compete with each other to produce the most and the 'best' marijuana, there is no reason to believe that the quality of street marijuana has remained consistent over time.

Because marijuana is the most commonly used illicit drug in the world, with reports of approximately 125 to 203 million people having used the drug in the last year (United Nations Office on Drugs and Crime, 2011), there has been a great deal of research conducted on its effects on users. The use of marijuana results in a variety of changes within the user's body that can have a range of affects on the user's life (Copeland, Gerber, & Swift, 2006). The focus of this review will again be limited to the research evidence on potential harm associated with marijuana use in the areas of: (1) impairment; (2) academic and social development; (3) general physical health; (4) mental health; and (5) and continuing drug use. The discussion presented in this review will concentrate on the use of marijuana within the general population and the empirical evidence for how marijuana use effects the general population in the previously listed five areas.

## **Methodology**

In the previous review by Diplock et al. (2009), the articles included were published between 2000 and 2007. The current review includes articles published between 2000 and 2012. Articles were identified by searching a number of databases, including Medline, PubMed, PsychINFO, and Google Scholar. Again, keywords related to each category were used to narrow the search and find appropriate articles.

Once an article was identified, it was assessed for appropriateness based on a review of the article's title and abstract. One potential limitation of this review was that only articles written in English were considered for this review. However, in order to expand the number of articles considered in this review, both original research studies and other literature reviews/meta analyses were included. In

order to ensure objectivity in the selection process, the inclusion or rejection of articles occurred without consideration of authorship or the conclusions or recommendations made by the authors. Given this, the articles considered in this review represented the continuum of current research on the harms that may be associated with marijuana use. Because of the scope of this topic and the amount of literature on marijuana use, the articles included in this review do not represent all available research on the effects of marijuana use. However, because many of the articles included in this review included extensive reviews of previous literature, the areas of focus for this review were well represented.

Finally, when considering the evidence presented in this review, it is critical to keep in mind that many of the studies based their results and conclusions on self-reported effects of marijuana use by the users themselves. While self-report studies are extremely valuable, they are susceptible to a variety of methodological problems, such as social desirability effects, errors in memory, exaggeration, and deception, which must be considered when evaluating results or conclusions (Palys, 1997). In addition, it is also extremely difficult to link or establish a direct causal relationship between drug use and other specific behaviours, as it is likely that behaviours or outcomes are the result of multiple factors, rather than exclusively one factor, such as drug use.

### **Marijuana-Related Impairment**

This section reviews the findings of literature related to both short-term and long-term impairment. It is important to understand the short-term and long-term effects of marijuana use on cognitive and motor skills, as impairment may present a serious risk, particularly for younger users and those who may operate motor vehicles soon after use. Impairment will likely be a major source of concern around public safety in the event that the legal responses to marijuana use changes.

### *Short-Term Impairment*

Impairment immediately after the consumption of marijuana may be a concern for users and the community at large. Recent research supports claims that marijuana impairs concentration, attention, planning, decision-making, and working memory (Crean, Crane, & Mason, 2011). Some effects, however, particularly those on attention, appear to be stronger in less experienced users, who have not built up tolerance to the drug, while heavy users may be more likely to experience impairments during short periods of abstinence (Crean et al., 2011). Since marijuana is a commonly used substance and research indicates that there may be close to 5% of drivers having THC in their system (Beirness & Beasley, 2009), these types of acute impairments may pose a risk to users and the general public.

Ilan, Smith, and Gevins (2004) determined that focusing attention and response accuracy were impaired immediately after smoking marijuana, even marijuana with less than 4% THC. Marijuana use resulted in difficulty maintaining a coherent train of thought and disruptions to selective filtering processes, both of which impaired memory (Ilan et al., 2004). Anderson, Rizzo, Block, Pearlson, and O'Leary (2010) found that marijuana had an impairment effect on attention, cognitive flexibility, and time estimation in their sample of both males and females. However, impaired attention was not found in a study of marijuana's effects on auditory focused attention tasks where participants responded to a tone by pressing a button as quickly as possible (O'Leary et al., 2007). Results of a double-blind test of marijuana's impairment of executive cognitive abilities by Vadhan et al. (2007) indicated that while marijuana caused an increase in the time used to make gambling decisions, the accuracy of decision-making was not impaired.

In their examination of brain functioning hours after using marijuana, Kanayama, Rogowska, Pope, Gruber, and Yurgelun-Todd (2004) found that heavy marijuana users did not present impaired abilities on simple spatial working memory tasks by compensating for deficits by employing regions of the brain not commonly used during such tasks. Smith, Longo, Fried, Hogan, and Cameron (2010) also found increased activation as well as increased blood flow to additional regions of the brain when marijuana users performed visuospatial working memory tasks. Howard and Menkes (2007) reported that acute marijuana intoxication was accompanied by impairment of brain function related to goal-oriented activities.

Although existing research indicates that short-term cognitive impairment can and does occur among marijuana users, the level of impairment is generally not serious. However, this does not suggest that there are no or few short-term risks of impairment associated with marijuana use. It is also important to note that most of the research to date has involved relatively small sample sizes, and with few exceptions, researchers are unable to control the dose of marijuana in their samples.

Despite the apparently minor levels of impairment reported in the existing research, there is evidence to suggest that marijuana use can have serious consequences for driving. Operating a motor vehicle can be a potentially dangerous activity at any time. However, doing so while impaired by marijuana significantly increases the risks of accident. Although studies revealed that recent marijuana use was a causal factor for only a small proportion of accidents, perhaps due to a lack of standardized roadside test instruments for marijuana impairment, short-term marijuana impairment does contribute to serious motor vehicle accidents (Bedard, Dubois, & Weaver, 2007; Blows et al., 2005; Laumon, Gadegbeku, Martin, & Biecheler, 2005). A meta-

analysis by Chen-li et al (2011) found that based on studies over the past twenty years, marijuana use by drivers significantly increases the risk of motor vehicle crashes. A Canadian study of fatally injured drivers conducted between 2000 and 2006 found that nearly 15% tested positive for marijuana use (Beirness, Baesley, Lecavalier, Boase, & Mayhew, 2009). Furthermore, research appears to support claims that driving after marijuana use is becoming more common (Bierness & Porath-Waller, 2009), with one recent study of university students in Toronto reporting that 35% of participants had driven under the influence of marijuana while only 5% reported driving while intoxicated by alcohol (McGuire, Dawe, Shield, Rehm, & Fischer, 2011).

Research has explored the relationship between marijuana induced cognitive impairment and operating a motor vehicle and found reasons for concern. Ramaekers et al. (2006) concluded that decision-making, planning, tracking, reaction time, and impulse control were all impaired by high-potency marijuana. Although the subjects were considered only light users, substantial impairment of executive and motor functioning for a period of at least six hours was found. Although the THC levels in the marijuana used in this study (13% THC levels) was higher than the averages reported by the 11% averages reported by Mehmedic et al., (2010) and the RCMP (2008), this study demonstrated that serious impairment lasting for many hours was common when consuming high potency forms of marijuana.

Field tests have found that impairment increases with the level of THC (Papfotiou et al., 2005; Khiabani et al., 2006), which presents further concern given the general trend of increased potency in available marijuana. Research by Ramaekers et al. (2000) concluded that even low levels of THC can moderately impair driving abilities, but driving is severely impaired when

either higher levels of THC marijuana is consumed or marijuana with lower levels of THC is consumed with even small amounts of alcohol. Considering the research examined for this section, there appears to be a strong consensus that marijuana use has a negative, and potentially harmful, effect on driving.

### *Long-Term Impairment*

The question of whether long-term marijuana use can lead to serious negative effects on cognitive capabilities has recently received increased attention from researchers (Pattij, Wiskerke, & Schoffemeer, 2008). Researchers have examined the potential for impairment as a result of long-term use, even during periods of abstinence (Pope, Gruber, Hudson, Huestis, and Yurgelun-Todd, 2001; Tapert et al., 2007). From the results of these studies, it appeared that, although heavy marijuana users showed impaired cognitive abilities after a week of abstinence, for most users, there were no noticeable impairments after a period of twenty-eight days of abstinence (Pope et al., 2001; Tapert et al., 2007). There is no consensus on the extent of the risk of long-term cognitive impairment from marijuana (Pattij et al., 2008), but research findings suggest that heavier use and earlier onset of use cause greater long-term deleterious effects (Crean et al., 2011).

Research on long-term marijuana users found an increase in brain activity in more regions of the brain when performing a variety of cognitive tests when compared to non-users (Kanayama et al., 2004; Tapert et al., 2007). The researchers concluded that this finding was the result of the brain working harder and differently to overcome the deficits resulting from the marijuana use. In addition to working harder and differently, Schneider et al. (2006) discovered significantly increased blood volumes in various regions of the brain, even after a

period of abstinence of six to thirty-six hours. The researchers indicated that it remained unknown how these changes affected brain functioning and whether these changes were permanent, long-lasting, or temporary. However, these findings do suggest that there is a potential for some types of long-term brain impairment.

When considering early-onset users to late-onset users, even after twenty-eight days of abstinence, Pope, Gruber, Hudson, Cohane, Huestis, and Yurgelun-Todd (2003) found that early-onset frequent marijuana users had a greater likelihood of suffering a range of cognitive functioning impairments, in particular verbal IQ, compared to late-onset and non users. A review by Jacobus, Bava, Cohen-Zion, Mahmood, and Tapert (2009) found that even after a month of cessation, adolescents tend to show negative effects on attention, learning, processing speed, brain structure, brain function, and sleep. However, the abnormalities appear to be relatively mild, with effect sizes generally smaller than those found for alcohol and other drugs, and the majority resolve after three months of abstinence (Jacobus et al., 2009). Most researchers agree that adolescence is a period of neurodevelopmental vulnerability, and that heavy marijuana use at this time likely puts youth at risk of long-term changes to the brain (Gruber, Sagar, Dahlgren, Racine, & Lukas, 2011; Jacobus et al., 2009; Pattij et al., 2008).

### **The Effects of Marijuana Use on Academic and Social Development**

As marijuana is the drug of choice for many young people, it is necessary to understand whether marijuana has any negative effects on academic performance and the transition from adolescence to adulthood. A number of studies suggest that marijuana is relatively easy for young people to access (Harrison, Erickson, Korf, Brochu, & Benschop, 2007; Johnston, O'Malley, Bachman, & Schulenberg,

2011). The evidence for both immediate impairment and the possibility of longer-term impairment support the notion that marijuana use may have negative consequences on the development of young users, which in turn could reduce their likelihood of having successful, productive, and happy lives.

### *Marijuana and School Performance*

There are many factors that contribute to academic achievement, such as general intelligence, interest/curiosity, motivation, lifestyle, and social relationships/networks. Since in adolescence the human brain is still in a developmental stage, it is possible that recreational marijuana use may disrupt 'normal' development (Gruber et al., 2011; Jacobus et al., 2009; Pattij et al., 2008), which may result in, among other things, poorer school performance. Lynskey and Hall's (2000) review of cross-sectional studies on marijuana and school-related issues concluded that marijuana appeared to have a strong relationship with absenteeism, lack of retention, and not graduating. Survey research by Bovet, Viswanathan, Faeh, and Warren (2006) revealed that students who were absent on the day of a school-based survey were more likely to use marijuana, alcohol, and cigarettes than students who were present. Research by van Ours and Williams (2009) found that marijuana negatively influences educational attainment, as users were more likely to drop out of school. This relationship was found to be particularly important for those users who began use prior to age 15 (Horwood et al., 2010). While marijuana appears to detract from academic achievement, recent research also indicates that academic issues, such as low grades, low participation in classroom activities, poor attendance, academic dishonesty, and incidents of discipline, are higher among those students who used marijuana at school than those who used, but did not use at school (Finn, 2012).

In an examination of the relationship between academic achievement and drug use in a wide range of students, Jeynes (2002) concluded that marijuana use, when examined alone, was statistically significantly related to lower standardized test scores in math, science, reading, and social studies. Average scores on the math comprehension test for marijuana users were further below the mean than

on any other test, while reading comprehension appeared to be affected the least. However, when marijuana was combined with alcohol or cigarettes, the results were much less robust. In effect, both regular smoking and alcohol intoxication explained much more of the variance, thus reducing the influence of marijuana on test scores. This may have been the result of the fact that it is rare for students to be under the influence of marijuana while at school (Jeynes, 2002). Similarly, Diego, Field, and Sanders (2003) found that grade point averages decreased as the reported frequency of marijuana use increased. Marijuana use had a larger negative correlation with grade point average as frequency of use increased ( $r = -.400$ ) than alcohol ( $r = -.355$ ) or cigarettes ( $r = -.221$ ) (Diego et al., 2003). Research by van Ours and Williams (2009) reported that females were more susceptible to the negative effects of marijuana use on education, while Horwood et al. (2010) found that marijuana was likely to interfere with a male's likelihood of participating in post-secondary education than for females. While these studies suggest the existence of an association between marijuana use and academic achievement, the research cannot establish that there is a direct causal relationship. There may be pre-existing differences between those students who use marijuana and those who do not, which explains their rates of dropping out, particularly since tobacco use is also related to lower educational attainment, but is less likely to impair cognition (McCaffrey, Liccardo Pacula, Han, & Ellickson, 2010). While it is unknown what the factors are that explain the association between marijuana use and lower education attainment, van Ours and Williams (2009) discuss the potential for reduced health, decreased interest in studying, impairments to cognitive functioning, or a combination. Regardless of the underlying reasons for marijuana use to negatively affect educational attainment, the consequences on future earning can be harmful and therefore, deserve continued attention.

Since marijuana has been linked to impairment and a decrease in school performance, researchers have studied the effects of marijuana on IQ (Fried, Watkinson, James, & Gray, 2002). However, measuring the direct effects of marijuana use on IQ has been difficult as there is rarely a baseline measure of a subject's IQ prior to their initiation into marijuana use (Copeland et al., 2006). In one longitudinal study that did have baseline measures of IQ prior to the subject ever using marijuana, Fried et al.

(2002) reported a statistically significant decrease in IQ score among individuals who smoked five or more marijuana cigarettes per week. On average, these researchers measured a 4.1 point decrease between the time the subject was 9 to 12 years old (no prior use) and 17 to 20 years old (current and/or past use). However, when considering the degree of marijuana use, only those characterised as heavy users showed any decreases in IQ compared to slight users, former users, and non-users who all demonstrated increases in IQ (Fried et al., 2002). These results suggested that marijuana use has an effect on general intelligence, but is more severe for regular and chronic marijuana users.

### *Marijuana Use and Later Social Development*

Success in adulthood is related to a wide range of developmental and social variables throughout childhood and adolescence. It has been hypothesised that many of these contributing dynamics could be negatively affected by the use of marijuana. For example, some people contend that one of the possible outcomes of marijuana use is chronic low motivation. In effect, the hypothesis is that marijuana use among young people contributed to the development of low motivation which has long-term effects on school and employment performance. In their research, however, Lynskey and Hall (2000) concluded that there was little evidence to support the low motivational syndrome hypothesis. Moreover, Eisen et al. (2001) reported that long-term (over 20 years), regular marijuana use among males was not associated with any specific negative socio-demographic effects such as alcohol or nicotine abuse or dependence, hospitalizations, and health-related quality of life.

However, other researchers have found several adverse associations between marijuana use and social development. A study of the relationship between marijuana use in high school students and later occupational attainment concluded that marijuana had differential negative associations with occupational attainment for males and females (Schuster, O'Malley, Bachman, Johnston, & Schulenberg, 2001). Similarly, Gren and Ensminger (2006) found that frequent adolescent marijuana use was associated with poorer academic achievement, a lack of stable employment, and family

dysfunction. These results suggested that using marijuana 20 or more times during adolescence was associated with being unemployed, unmarried, and becoming a parent while unmarried (Green & Ensminger, 2006). A study by Stuart and Green (2008), which used full matching to explore the effects of adolescent marijuana use on adult outcomes, also found that early marijuana use was associated to an increased risk of poverty, lower household income, and having had a period of unemployment. These effects were not observed for males, but heavy marijuana users of both genders were at increased risk of further serious drug use (Stuart & Green, 2008). Fergusson and Boden (2008) concluded that early marijuana use was associated to poorer educational outcomes, unemployment, increased likelihood of dependency on welfare, lower satisfaction with one's life and relationships, and lower income. Pedersen (2011) also found that marijuana users were more likely than non-users to later receive welfare, less likely to leave welfare, and receive welfare for longer durations.

When the findings from studies related to occupational attainment and school performance are considered together, it appears that marijuana use among young people can have a detrimental outcome on their future. However, these findings do not confirm a causal relationship between marijuana use and poor performance in school or life. Still, the evidence does suggest that, even in the absence of a direct causal link, the use of marijuana during adolescence, for many young people, is often accompanied by other factors, such as the development of delinquent peer associations or a general lack of commitment to prosocial activities and institutions, which can lead to problems with social development.

### **General Health Consequences of Marijuana Use**

The use of marijuana introduces foreign substances into the body and produces a number of chemical changes in the user's brain and body. Given this, there is a large literature focusing on the physical effects of marijuana. To begin, there is little evidence to suggest that marijuana use poses a serious risk for an overdose death or its infrequent use is related to the development of long-term health problems (Copeland et al., 2006). This section focuses on the link between marijuana use and general health issues such as respiratory ailments, heart problems, threats to the immune system, potential

reproductive harms, and the risks for cancers. The section ends by exploring the effects of dependency and withdrawal symptoms.

### **Respiratory Ailments Related to Marijuana Use**

The most common way of using marijuana is by smoking it. A direct consequence of this method of consumption is that smoke must enter the airways and lungs of the user. A past review by the authors (Diplock & Plecas, 2009) found a number of respiratory risks and harms related to marijuana use. Marijuana smoke contains many of the same poisons found in tobacco smoke (Lang 2007; Taskin, 2005), and this has led research to be focused on determining whether the respiratory outcomes of smoking marijuana are similar, less problematic, or worse than those associated with smoking tobacco (Copeland et al., 2006). One reason to believe symptoms may be worse in marijuana smokers is the way in which it is smoked, often unfiltered, with larger puffs, deeper inhalations, longer breath holding, and the use of the Valsalva manoeuvre (Lang, 2007). In their review of the research literature, Taylor and Hall (2003) argued that marijuana should be considered as damaging to the airways as tobacco. Aldington et al. (2007) argued that one marijuana cigarette had the potential lung obstructing effects of two to five tobacco cigarettes.

Taylor, Poulton, Moffit, Ramankutty, and Sears (2000) reported that respiratory symptoms were significantly more prominent in marijuana-dependent users than in non-users. The sample consisted of a group of 21 year old subjects from the 1970s who self-reported short histories of smoking marijuana (Taylor et al., 2000). The associated self-reported respiratory problems included wheezing, shortness of breath after exercise, nocturnal chest tightness, and early morning phlegm and mucus. These symptoms, which are typically indicative of chronic bronchitis, were also found to be associated with smoking marijuana in the research by Moore, Augustson, Moser, and Budney (2005). Overall, recent research suggests that most occasional marijuana smokers will not face serious negative respiratory

consequences, but that regular heavy use will likely cause accelerated declines in pulmonary functioning (Pletcher et al., 2012).

There is currently no consensus on whether marijuana smoking causes airflow obstruction. Taylor and Hall (2003) argued that there was a strong possibility that smoking marijuana was a contributing factor to the development of chronic lung disease. Further research by Tetrault, Crothers, Moore, Mehra, Concato, and Fiellin (2007) concluded that long-term marijuana smoking was also associated with an increase in airflow obstruction and obstructive lung disease. Aldington et al. (2007) argued that marijuana smoking may put users at risk of chronic obstructive pulmonary disease (COPD). However, Taskin (2009; 2010) argues that it is unlikely that marijuana smoking alone causes COPD, and research from Tan et al. (2009) reports that marijuana smoking may have an additive effect to COPD for those users who also smoke tobacco cigarettes, but that marijuana smoking alone was not associated to COPD.

Marijuana smoking does appear to have other effects on lung functioning. Marijuana use has been associated to higher lung volumes and hyperinflation (Hancox et al., 2010; Taskin, 2010). While the mechanism and consequences of these effects are unclear, they may be linked to other, serious though less common, conditions (Taskin, 2010). Research has found that marijuana smoking may be associated with serious respiratory conditions such as bullous lung disease (Hii, Tam, Thomson, & Naughton, 2008), collapsed lung (Beshay, Kaiser, Neidhart, Reymond, & Schmid, 2007; Gill, 2005), pulmonary fibrosis, byssinosis, and lung tumours (Phan, Lau, & Li, 2005). At this time there has not been enough research to provide estimates of the prevalence of these conditions.

Since many of the detrimental effects on the respiratory system are the direct result of smoking, there have been several studies examining whether vaporizers provide a less harmful way to consume marijuana (Earleywine and Barnwell, 2007; Hazekamp et al., 2006; Van Dam & Earlywine, 2010).

Based on self-reported respiratory symptoms after using vaporizers to inhale marijuana cannabinoids, Earleywine and Barnwell (2007) concluded that vaporizers did provide some measure of safety, especially as the amount of marijuana inhaled increased. Hazekamp et al. (2006) reached a similar conclusion. More recently, Van Dam and Earlywine (2010) conducted a small-sample pre-post test of vaporizers and found that the many respiratory symptoms were improved. The authors recommended that large-sample tests were needed to determine the viability of vaporizers as tools for harm reduction strategies (Van Dam & Earlywine, 2010).

While the use of vaporizers may eliminate or reduce some of the respiratory ailments for users, the THC in marijuana may pose another respiratory risk. As a response to the presence of THC, human airways experience cellular changes, especially to the mitochondrial energetic, which is responsible, in part, for the health of cells and their energy production (Sarafian et al., 2005; Sarafian et al., 2006). As expected, these changes were more significant with higher concentrations of THC and longer exposure times (Sarafian et al., 2005). In effect, as a result of THC in the lungs and airways, the risk of adverse pulmonary conditions is substantially increased (Sarafian et al., 2005; Sarafian et al., 2006).

### *Potential Harms of Marijuana Use on the Heart and Cardiovascular System*

One direct outcome from using marijuana is an immediate increase in heart rate. It is estimated that marijuana use increases the heart rate 20% to 50% immediately following consumption (Copeland et al., 2006). This has led researchers to examine the short and long-term implications of marijuana use on the heart and the circulatory system. The majority of research in this area relies on case studies (Basnet, Mander, & Nicolas, 2009; Caldicott, Holmes, Roberts-Thomas, & Mahar, 2005; Lindsay, Foale, Warren, & Henry, 2005; Rezkalla, Sharma, & Kloner, 2003; Safaa, Markham, & Jayasinghe, 2012), which limits the generalizability of findings, but there are studies with larger sample sizes (Mittleman, Lewis, Maclure, Sherwood, & Muller, 2001; Vandry, Umbricht, & Strain, 2011). While effects on the heart and cardiovascular system can be very serious and may afflict marijuana users, it

must be kept in mind that there is little evidence to suggest that the outcomes discussed are typical or the norm for most users.

Based on their case study of a 34-year-old man who reported heart fluttering and near syncope after marijuana use, Rezkalla et al. (2003) suggested that marijuana was a likely contributor to the decrease in coronary blood flow and ventricular tachycardia experienced by their subject. Lindsay et al. (2005) described two cases; one in which a man with a history of heart problems suffered arrhythmia precipitated by marijuana use, the second described a young patient who suffered an onset of myocardial infarction. Based on these case studies, the researchers concluded that marijuana was a serious concern for those who may be predisposed to heart-related illnesses (Lindsay et al., 2005). Similarly, Caldicott et al. (2005) documented the case of a young patient who suffered a heart attack after marijuana use, despite having no other identifiable risk factors for a cardiac event. A case-study of a 17 year-old also found that marijuana may have played a role in reduced blood supply to the heart muscle (Basnet et al., 2009). Safaa et al. (2012) also identified coronary vasospasms resulting from reduced blood supply to the heart muscle as a potential risk of marijuana use based on a case study of a 40 year-old patient.

There have been other studies that have used larger samples to identify risks associated with marijuana use. A study by Mittleman et al. (2001) concluded that, although it was less common than other stressors, marijuana use was a trigger for myocardial infarction. In this study, the risk of onset of myocardial infarction increased approximately five-fold in the first hour after use (Mittleman et al., 2001). Marijuana is also a risk factor in clinically significant increases in blood pressure for some users after abrupt abstinence, particularly for those who already have hypertension (Vandrey et al., 2011). Mukamal, Maclure, Muller, and Mittleman (2008) reported that their findings suggested that marijuana use should be considered a particularly serious risk for those who have survived myocardial infarction and those with coronary heart disease.

When the research literature is considered, the conclusion is that marijuana use may, in rare instances, trigger a heart attack or other serious cardiovascular problems. Additionally, there have been instances in which a young person has experienced symptoms similar to Brugada Syndrome (Pratap & Korniyenko, 2012), a heart condition that is closely linked to sudden deaths. However, it is important to recognise that the evidence linking marijuana use to serious heart and cardiovascular effects may be confounded by the subject's participation in a wide range of other unhealthy habits and genetic predispositions. Still, there is evidence to conclude that marijuana can be harmful to the heart, and researchers, such as Aryana and Williams (2007), have voiced a belief that heart problems related to marijuana use may be more common than currently recognized. In addition, they warned that as the population of marijuana users aged, continued use may increase the risk for a number of adverse cardiovascular issues, such as tachyarrhythmia, acute coronary syndrome, vascular complication, and congenital heart defects (Aryana and Williams, 2007).

### *Consequences of Marijuana Use on Reproduction and Pregnancy*

Research has explored the effects of marijuana use on sperm and egg development and the short and long-term outcomes for the foetus. This literature focuses on the relationship between drug use and implications for fertility and healthy, successful pregnancy. There is evidence to suggest that marijuana use can disrupt fertility and have other negative reproductive consequences.

Several studies have investigated the effects of marijuana use on male sperm fertility (Badawy et al., 2009; Rossato, 2008; Schuel et al., 2002; Whan, West, McClure, & Lewis, 2006). Scheul et al. (2002) found that the presence of THC in the reproductive fluids of both males and females could inhibit the ability of sperm to complete fertilization. Whan et al. (2006) also concluded that THC inhibited male fertility by binding to sperm cells and impairing sperm functions. More recent research suggests that there is a consensus that the THC and other cannabinoids in marijuana inhibit the sperm fertility

(Rossato, 2008). While all of the causal mechanisms have not been confirmed, one major contributor may be the fact that cannabinoids interfere with mitochondrial respiration and the production of energy for the sperm (Badawy et al., 2009; Rossato, 2009).

Marijuana use may also affect female fertility (Jukic, Weiberg, Baird, & Wilcox, 2007; Lee, Oh, & Chung, 2006). In females, marijuana was found to disrupt the endocrine system and produce an estrogenic effect, which can have detrimental effects on specific elements of the female reproductive system (Lee et al., 2006). It should be noted, however, that the effects were more the result of the contaminants of smoking the drug than the psychoactive chemicals (Lee et al., 2006). In addition, Jukic et al. (2007) determined that marijuana use negatively affected female reproductive hormones and could lead to delayed ovulation.

Overall, THC and other cannabinoids interact in a number of ways with the reproductive systems of both males and females. One recent review (Bari, Battista, Pirazzi, & Maccarrone, 2011) identified a number of risks marijuana use poses to the reproductive system. The authors indicated that males can experience a reduction in libido, problems with ejaculation, impaired sperm motility, reduced sperm counts, and impotence (Bari et al., 2011). Similarly, females can experience disruptions to the menstrual cycle, problems with ovulation, and impairment to the implantation and development of embryos (Bari et al., 2011). As the role of cannabinoids in human fertility is complex, even though researchers are currently exploring how these chemicals can be used to treat fertility problems in men and women, it is important to note that the use of marijuana may put users at risk of fertility problems.

As have been identified with the use of other drugs, there may be harms associated to the use of marijuana by pregnant mothers, particularly to the unborn foetus. Kuczkowski (2007) reported that THC crosses the placental barrier, but that there was no confirmation that it had a teratogenic effect. In other words, there is no evidence that marijuana use by a pregnant mother contributes or causes birth

defects or malformations. Based on their review of the research literature, Fried and Smith (2001) concluded that the effects of prenatal exposure to marijuana were subtle with little evidence supporting growth or behavioural effects prior to age three. However, research by Wang et al. (2006) determined that impairment was present in foetuses exposed to marijuana. Moreover, research from El Marroun et al. (2009) indicated that intrauterine exposure to marijuana, even for short durations, can lead to a number of issues such as low birth-weight, reductions to body and head growth when compared to children born without exposure. Similar findings including preterm labour were reported by Hayatbakhsh et al. (2012).

There may be longer-term emotional and behavioural implications for children exposed to marijuana while in the womb. Day et al. (2006) concluded that there was a statistically significant association between prenatal exposure to marijuana and later use; however, these researchers also concluded that there were many other potential factors that could have contributed to later marijuana use among those exposed to the drug while in the womb. Findings from a study by Goldschmidt, Richardson, Willford, and Day (2008) indicated that children who were exposed to marijuana while in the womb had significantly lower school-age intellectual development. However, these findings reflected use by mothers of at least one marijuana cigarette per day during pregnancy (Goldsmith et al., 2008).

Maternal use of marijuana was not associated to later psychotic symptoms in offspring in a study exploring the potential of prenatal exposure to alcohol, tobacco, and marijuana (Zammit et al., 2009). However, El Marroun et al. (2011) found that intrauterine exposure to marijuana increased the risk of aggressive behaviour and attention problems in children at 18 months of age. This was only found for girls, and the authors indicated a need for further exploration (El Marroun et al., 2011). Also, Day, Leech, and Goldschmidt (2011) found that youth at age 14 who had been exposed to marijuana while in the womb were more likely to be involved in delinquent behaviour, partially due to the effects that prenatal exposure to marijuana had on increasing depressive symptoms and attention problems in childhood.

While the previous review was unable to identify many serious risks of maternal marijuana use (Diplock et al., 2009), it is now becoming more clear that exposure to marijuana while in utero may have negative implications for children. It is likely that the harms become increasingly likely with greater consumption of marijuana during pregnancy (Day et al., 2011; Goldschmidt et al., 2009), and therefore efforts to stop or at least reduce marijuana use by pregnant women would appear warranted (Hayatbakhsh et al., 2012). While more research is still needed to determine if there are even more risks of use during pregnancy, it is important for potential parents to understand that marijuana use during pregnancy can potentially affect a child's physical and neuropsychological development (Day et al., 2011; Goldschmidt et al., 2009; El Marroun et al., 2009).

### *Marijuana Use as a Potential Threat to the Immune System*

THC and other cannabinoids from marijuana use may impair the immune system functions of various cells. If the immune system is compromised by the use of marijuana, there may be significant implications for the health of users (Copeland et al., 2006). The relationship between marijuana use and deficiencies in the immune system is based, in part, on the findings that THC inhibits the ability of T-cells and alveolar macrophages to protect the body from foreign pathogens (Tashkin, Baldwin, Sarafian, Dubinett, & Roth, 2002; Tashkin, & Roth, 2006; Shay et al., 2003). Alveolar macrophages are a main defence against infections in the lungs. A review of the research literature in this area by Copeland et al. (2006) suggested, however, that it might require high doses of THC to substantially impair immune system functioning. Recently, research has tended to focus on the effects of THC and other cannabinoids on alleviating symptoms related to serious medical conditions involving the immune system (Pacher & Gao, 2008; Tanasescu & Constantinescu, 2010). While it appears that these constituents of marijuana may have the potential for therapeutic uses as a result of their anti-inflammatory and immunosuppressive effects, there may also be risks of negative effects, such as serious infections, if used either medically or recreationally, particularly for those with previously compromised immune systems (Gargani, Bishop, & Denning, 2011).

### *Cancer Causing Effects of Marijuana*

Because marijuana smoke contains many of the same harmful carcinogens as tobacco smoke, there is a possibility that marijuana use may be associated with the onset of various types of cancers (Tashkin et al., 2002). While there are cases in which cancers appear to be caused by substantial marijuana use (Graef, Choo, Warfield, Cullen, & Woolhouse, 2011), to date, research has been inconclusive about the link between marijuana use and cancer. There are many of the methodological difficulties in attributing cancer outcomes specifically to smoking marijuana (Mehra, Moore, Crothers, Tetrault, & Fiellin, 2006). For example, in many instances, marijuana users also smoke tobacco, there is the challenge of determining proper thresholds for marijuana use, and the research has typically included only small sample sizes.

Since the most common method of administration for marijuana use is smoking, lung cancers have received research attention. In their study, Hashibe et al. (2006) failed to find substantial evidence for an association between marijuana use and lung or upper aerodigestive tract cancers. A study by Berthiller et al. (2008) concluded that marijuana smoking did increase the risk of lung cancer, but since every subject in their marijuana smoking sample also smoked tobacco, the effects of confounding variables could not be ruled out. Aldington et al. (2008b) also reported that long-term marijuana smoking increased the risk of lung cancer, but this conclusion was challenged by Sewell, Cohn, and Chawarski (2008) on the basis of methodological issues and the interpretation of an association as causal.

Other research on other kinds of cancer has been equally inconclusive. Rosenblatt et al. (2004), in their large-sample study, concluded that marijuana was not associated to oral squamous cell carcinoma. Aldington et al (2008b) found no increased risk of head and neck cancer, although the duration use studied may have been too short for a long-term effect to appear in the data. Liang et al. (2009) reported that moderate use of marijuana may in fact reduce the likelihood of head and neck squamous

cell carcinoma. There was also no link between maternal or paternal marijuana use and risk of childhood acute myeloid leukaemia (Trivers et al., 2006).

There are many researchers who believe that the changes to a variety of cells in the body caused by marijuana use may contribute to the development of cancers including lung cancer, oral cancers, and breast cancer (Cho, Hirsch, and Johnstone, 2005; Mehra et al., 2006; Lee et al., 2006; Tashkin et al., 2002). Research on testicular germ cell tumours (TGCT), a rare form of cancer accounting for less than 2% of cancers in men, have found an association between this disease and marijuana use (Daling et al., 2009; Trabert, Sigurdson, Sweeney, Strom, & McGlynn, 2011). Daling et al. (2009) found that men with this condition were more likely to use marijuana than controls, indicating an association between marijuana use and this type of cancer. Trabert et al. (2011) reported a two-fold increased risk of TGCT association to regular marijuana use. While neither study could confirm the causal mechanism for the increased risk, both recommended further research on this topic (Daling et al., 2009; Trabert et al., 2011). Indeed, more research is needed to explore the potential for marijuana to be associated to a number of cancers, and also for any potential protective qualities of the cannabinoids against cancers to be explored.

### *Marijuana Dependency and Withdrawal*

Despite the commonly held belief that marijuana use does not lead to addiction, existing research has often referred to a dependency on the drug (Copeland et al., 2006). Although many people use marijuana on a regular basis, Looby and Earleywine (2007) reported that fewer than half of all daily users exhibited the behaviours necessary to meet the established criteria for being classified as drug dependent. These criteria include tolerance, withdrawal, taking the drug for longer periods of time or larger doses than intended, inability to stop or reduce use, increasing the time spent obtaining the drug and recovering from its effects, ignoring other important activities, and continuing use despite undesirable consequences. Looby and Earleywine (2007) argued that dependence was not a necessary

result of frequent use, but that it may be a contributing factor. Their research suggested that negative effects of marijuana use, such as dissatisfaction with life, low motivation, and unhappiness, were more related to dependence on the drug than regular use (Looby & Earleywine, 2007). When considering the results of Looby and Earleywine's research with findings from Copersino et al. (2006) on withdrawal symptoms, strong support is established for the idea that a proportion of frequent marijuana users suffer negative effects resulting from a dependency.

Hasin et al. (2008) reported that withdrawal was prevalent among a sample of regular marijuana users. The commonly reported symptoms include weakness, hypersomnia, sleeping, yawning, depression, and feelings of anxiety or nervousness (Hasin et al., 2008). Bonn-Miller and Moos (2009) found that those in treatment for marijuana abuse who were more frequent users were more likely to experience anxiety after abstaining from use. Higher levels of anxiety and more frequent use were found to be significant predictors of relapse (Bonn-Miller & Moos, 2009). Levin et al. (2010) found that withdrawal symptoms were associated to failed attempts to quit use, as the drive to relieve the symptoms can cause users to relapse. Furthermore, withdrawal symptoms are prevalent even among marijuana users who do not exhibit other drug dependencies (Hasin et al., 2008).

In terms of factors that most likely contribute to the development of a marijuana dependency, Hall (2006) reported that initiation to drug use at an early age was the most significant factor. However, in terms of public policy, if THC levels are indeed increasing and continue to increase, there will likely be a growing number of users who find themselves dependent on the drug. This may prove to be more problematic if future research establishes additional and more serious negative health consequences of long-term use as users may experience more difficulty abstaining from use even in the face of exacerbating social and health problems. Researchers have suggested that marijuana dependency and withdrawal have serious clinical consequences, should be included in the DSM-V, and are a legitimate area for focused treatment (Hasin et al., 2009; Levine et al., 2010).

## **Marijuana Use and Mental Health**

In addition to some potentially serious physical health problems, marijuana use has also been associated with mental health problems. While this topic had received a great deal of attention in research, the documentary film associated to the CBC's *The Nature of Things* titled *The Downside of High* (Mohun, 2010) brought the association between mental illness and marijuana into the public spotlight in Canada. The link between marijuana use and psychosis or later schizophrenia has possibly received the most attention in the research literature. However, there is research that associates marijuana use to other mental health issues including depression and anxiety.

### ***Marijuana-Precipitated Psychosis and Schizophrenia***

An association between marijuana use and the onset of psychosis has become a serious concern. Research suggests that 8% to 10% of all cases of psychosis may be triggered by the use of marijuana (Arseneault, Cannon, Witton, & Murray,; Linszen and Van Amelsvoort, 2007). Ferdinand et al. (2005) concluded that marijuana use was linked to psychosis independent of any previous mental pathology. Moore et al. (2007) argued that there was enough evidence to support a public warning that marijuana use increases the chances of suffering from a psychotic illness. The risk may be more pronounced for those who are already vulnerable for this type of mental affliction (Arseneault et al., 2004; Degenhardt and Hall, 2006; Linszen and Van Amelsvoort, 2007). In order to explain this relationship, Caspi et al. (2005) reported that there may be an interaction between the chemicals typically present in marijuana and a number of 'susceptible' genes in the user that contributes to the onset of marijuana-induced psychosis and schizophrenia. It is also likely that state of brain development during adolescence creates greater vulnerability to psychotic effects from marijuana use and perhaps even schizophrenia (Malone, Hill, & Rubino, 2010). Other recent research also suggests that earlier age of onset for marijuana use is associated to earlier expressions of psychotic symptoms in those who are predisposed (Dragt et al., 2010).

If marijuana use triggers psychosis, it might be a risk factor for schizophrenia (Arsenault et al., 2004; Arendt, Rosenberg, Foldager, Petro, & Munk-Jorgensen, 2005; Caspi et al., 2005). In a study to determine whether those who suffered from an episode of marijuana-induced psychosis were at risk of developing later schizophrenia, Arendt et al. (2005) found that marijuana-induced psychosis was an important risk factor for developing schizophrenia and that often symptoms began earlier than they did for those with no self-reported marijuana use. Solowij and Michie (2007) found similarities between the cognitive effects of marijuana use and the cognitive endophenotypes of schizophrenia.

One of the complications for fully understanding marijuana's association with psychosis and later schizophrenia is that people with mental illness may continue to use the drug. Grech, Van Os, Jones, Lewis, and Murray, (2005) investigated the effects of marijuana use in patients who had recently suffered from psychosis to determine whether symptoms were prolonged and worsened by the drug. From their findings, it appeared that those who continued to use marijuana were at a greater risk of having more symptoms and a continuous course of mental illness (Grech et al., 2005). It could not be confirmed from their study, however, whether marijuana made the symptoms worse or the degree to which marijuana directly contributed to the symptoms. Dekker, Linzen, and De Haan (2009) reviewed studies that asked patients suffering from psychotic symptoms why they used marijuana and what the effects were. The results indicated that while marijuana was used because it was perceived to improve relaxation, affect, and sociability, many patients reported negative effects (Dekker et al., 2009). A 10-year follow-up study of patients hospitalized for schizophrenia spectrum disorders revealed that continued marijuana use was associated with more severe psychotic symptoms independent of other factors (Foti, Kotov, Guey, & Bromet, 2010). It was also found that those suffering from more severe psychotic symptoms were more likely to use marijuana, which has important implications for treatment.

There are a number of hypotheses in the research literature about the nature of the relationship between marijuana use and psychotic symptoms (Degenhardt, Hall, & Lynskey, 2002; Hall, 2006;

Hall and Degenhardt, 2000; Smit, Bolier, & Cuijpers, 2004). The most common hypotheses were that: (1) marijuana use causes psychosis and schizophrenia without any existing predisposition; (2) marijuana use triggered the onset of these symptoms in people who were previously vulnerable; (3) marijuana use exacerbated the symptoms in those already suffering; and (4) those already suffering from these symptoms were more likely to self-medicate with marijuana. Based on the research, the strongest support was for the second and third hypotheses, with the self-medicating hypothesis failing to find any support.

The causal hypothesis remains debatable. Degenhardt and Hall (2002) found that cases of schizophrenia in the general population did not rise with an increase in reported marijuana use, thus weakening the case for the causal hypothesis. While multiple cohort studies that measure marijuana use and incidence of psychosis have found support for the general direction of a causal relationship, there is not enough evidence to claim that marijuana use causes schizophrenia or psychotic disorders that would not have otherwise occurred (McLaren, Silins, Hutchinson, Mattick, & Hall, 2010). While suggesting that marijuana use is neither necessary to cause schizophrenia or capable of doing so in and of itself, D'Souza, Sewell, and Raganathan (2009) argued that it may be a component cause, meaning that exposure to marijuana's cannabinoids, when combined with other factors, may cause a psychotic disorder. Further research is needed to more fully understand whether there is a causal relationship between marijuana use and psychosis, and to determine what the mechanisms are that may cause the cannabinoids to contribute to these types of mental illnesses. However, based on the research to date, psychosis and later schizophrenia as a result of marijuana use should be viewed as a potential risk for a small portion of marijuana users.

### *Depression and Anxiety among Marijuana Users*

There is a larger body of research exploring the link between marijuana use and psychosis and schizophrenia than there is for other mental health issues associated with marijuana use. However,

research has explored marijuana's link to other mental health issues such as depression and anxiety. Diego et al. (2003) found that increased marijuana use among high school students, like the use of cigarettes and alcohol, was associated with increased self-reports of depression. However, Harder, Morral, and Arkes (2006) found that past-year marijuana use was not a significant predictor of future development of depression. Harder, Stuart, and Anthony (2008) found that depression may be a moderate risk for males who use marijuana, but that findings suggested that it did not contribute to depression in females. Similarly, research by Bonn-Miller, Zvolensky, Leen-Feldner, Feldner, and Yartz (2005) found that marijuana use was a predictor of anxiety symptoms, but not for depression. A study of marijuana use among high school students found that marijuana users had higher rates of both depression and anxiety, and that marijuana use was independently associated to measures of suicidality. Buckner, Joiner, Schmidt, and Zvolensky (2012) found a link between marijuana use and high social anxiety, which were also related to suicidality. Daily marijuana users with high anxiety had the highest levels of suicidality (Buckner et al., 2012). Furthermore, those dealing with problems associated to marijuana use may be more likely to exhibit social avoidance behaviours (Buckner, Heimberg, & Schmidt, 2011). Again, it remains a challenge to determine whether marijuana use is a cause of these symptoms, whether it exacerbates the symptoms in those who already exhibit them, or if the symptoms play a contributing role in marijuana use.

### **Marijuana's Role in Continuing Drug Use**

The discussion of potential harms of marijuana use presented thus far indicated that marijuana poses a number of potential risks to the general population of users and some specific negative outcomes for a relatively small subgroup. The risk or actual harms associated with marijuana use can be seriously compounded by the use of other drugs, and can become overshadowed by the dangers associated with becoming addicted to 'harder drugs'. Moreover, there has long been the suggestion that marijuana can act as a 'gateway' for other drug use. It would appear that the probability that marijuana acts as a gateway to other illicit drugs is much higher than the other way around (Fergusson & Horwood, 2000). According to Fergusson and Horwood, when adjusting for other common covariate factors such as

childhood, family, and life-style factors, regular marijuana use (fifty or more times in a year) was strongly related to the onset of further illicit drug use. However, Morral, McCaffrey, and Paddock (2002) found that the opportunities presented by the lifestyle accompanying marijuana use were just as likely to predict the use of other illicit drugs as was the use of marijuana.

Since the majority of marijuana users do not continue on to other illicit drugs (Fergusson and Horwood, 2000), it is important to understand what factors distinguish between those who do and those who do not go on to use other illicit drugs. The policy and control responses are likely to be very different depending on whether the relationship is based on the effects of marijuana use or on the lifestyles that accompanied marijuana and other illicit drug use. Twin studies have established that marijuana use is a strong predictor of future illicit drug use regardless of the familial and environmental similarities between twins (Lynskey, Vink, & Boomsma, 2006). However, other research focusing on both monozygotic and dizygotic twins suggested that it is more likely that individual genetic traits explain the progression of marijuana to other drugs than does a triggering effect from the marijuana itself (Cleveland & Weibe, 2008). Agrawal et al. (2007) came to a similar conclusion that there is strong evidence of confounding factors such as genetics and lifestyle explaining the relationship between early marijuana use and later use of other illicit drugs, but the “gateway” effect could not be discredited. Recent data from a study by Van Gundy and Rebellon (2010) found that the link between adolescent marijuana use and adult use of other illicit drugs is more a factor of stress and other life-course variables than of a “gateway effect”. Degenhardt et al. (2010) also suggested that much of the progression to other illicit drugs was likely the result of other common causes, and that preventing the use of so-called “gateway drugs” will not likely lead to large reductions in the use of other illicit substances.

Overall, it is known that marijuana users are at an increased risk of continuing on to other illicit drugs. In fact, research suggests that it is rare for marijuana use not to have preceded the use of other illicit drugs (Van Gundy & Rebellon, 2010). However, this may be more the result of the user than the drug.

While it is most probable that pre-existing individual and environmental risk factors or lifestyle factors associated to marijuana use explain the “gateway effect”, there is not enough evidence to fully disprove the gateway theory. The hypothesis that pharmacological effects of marijuana use independent of other factors increase the likelihood of using other illicit drugs has yet to show strong evidence (Agrawal et al., 2007), although researchers continue to test this hypothesis (Fergusson, Boden, & Horwood, 2006; Lessem et al., 2006). Even with what is known, a better understanding of the potential causes or correlates for this association are needed to determine how changes to marijuana’s current legal status would impact patterns, rates, and additional harms of other drug use.

## Conclusions

The discussion of the appropriate policy direction on marijuana use needs to be informed by up-to-date and unbiased research on the harms it may present to users. Based on a review of the current literature, it can be concluded that marijuana does pose some considerable risks to users. Concern over marijuana is merited by findings regarding its ability to create short-term impairment, specifically on driving ability. Academic performance and social development appear to be negatively affected by marijuana use, but the causal role that the drug plays in the lack of future success of young people remains unconfirmed. As expected, smoking the drug contributes to considerable harm to the lungs and airways. Even though the use of vaporizers removes the contaminants of combustion and reduces some major respiratory problems, THC exposure to the lungs appears to be unhealthy. The immune system is also compromised by the use of marijuana, specifically the ability of the lungs to defend against foreign pathogens. Although cancers, heart problems, and threats to human reproduction are not common among marijuana users, most experts contend that further investigation is required and the potential for risk should not be dismissed. The development of psychosis and later schizophrenia should also remain a concern for a small proportion of those who use marijuana. Dependency and regular, long-term use of the drug are also factors that likely exacerbate the potential for the majority of the harms previously identified in this review. Of course, these harms are often compounded by the fact that marijuana users have an increased likelihood of continuing on to other illicit drugs.

With a growing amount of research on the potential therapeutic benefits of marijuana and its constituent cannabinoids, there is a responsibility on those who advocate for its medical use to ensure would-be patients are adequately informed of the risks. As is the case with other drugs used for medical purposes, marijuana can have negative effects which could outweigh the benefits if used incorrectly. It is particularly important for messages to be crafted in such a way that the general public and potential recreational users do not misinterpret the potential medical benefits as evidence that marijuana use is completely risk-free. Similarly, if public policy moves toward decriminalization or legalization, the process needs to ensure that the policy rationale for the decision (i.e. increased taxation, reduced criminal justice costs, potential effects on organized crime, etc) does not send the message that the change to the legal status was based on the fact that the drug poses no risk.

Although very serious consequences from marijuana use are relatively rare, it should be acknowledged by all that the lives of a small proportion of the population will be seriously disrupted by marijuana use. The debate over the appropriate way to respond to marijuana use in society requires advocates both of decriminalization and of prohibition to concede that marijuana is neither harmless, nor is it particularly dangerous to the majority of users. With an understanding of the potential harms associated to marijuana use forming the basis of the debate, politicians, policymakers, and citizens can make responsible decisions about the legal status of the drug. By understanding that marijuana can and does cause harm to users, whether it is prohibited, decriminalized, or legalized, all concerned are in a better position to address those questions that must be answered in order to move forward. Among many others, those close to the debate need to consider the following questions: Are we willing to accept that some members of society will be harmed by marijuana use, and are taxpayers willing to pay associated costs? What lessons can be learned from the experiences with alcohol that might apply to marijuana? Are there other or better approaches than prohibition to manage the problems that marijuana use creates? Would changing the legal status promote increased marijuana use, reversing current decreasing trends? Would removing the prohibition of marijuana improve our ability to mediate the known harms, or would it result in even greater social harm?

To date, the research evidence shows that marijuana has a number of associated harms. In some cases, these harms are worse than those associated with regulated substances, such as alcohol or tobacco.

Based on the course of research, it is likely that future studies will further refine our understanding of the harms of marijuana use. It is possible that as time goes on, a greater number or more serious harms will be identified, or that answers to currently unanswered questions will reveal that there are relatively fewer risks than is now believed. Additionally, new research may discover ways to substantially limit the amount of harm caused by marijuana use. New information related to the harms of marijuana use should purposefully be brought into the discussion about how to deal with this issue. In any case, it is necessary that researchers disseminate their latest findings in a wide range of ways in order for the public to have the best information at their disposal about the harms and risks associated with using marijuana.

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### **Conflict of Interest Statement:**

On behalf of my co-authors, Jordan Diplock (RCMP Research Analyst), Len Garis (Adjunct Professor at the University of the Fraser Valley), and myself (Darryl Plecas, RCMP Research Chair and Director, Centre for Public Safety and Criminal Justice Research, University of the Fraser Valley, and Board Member, Canadian Centre on Substance Abuse), I declare that we have no proprietary, financial, professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled “An Updated Review of the Research on the Risks and Harms Associated to the Use of Marijuana”.

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