The dynamics of cannabis use and dependence

van der Pol, P.M.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
VALIDATION OF SELF-REPORTED CANNABIS DOSE AND POTENCY: AN ECOLOGICAL STUDY
ABSTRACT

Aims. To assess the reliability and validity of self-reported cannabis dose and potency measures.

Design. Cross-sectional study comparing self-reports with objective measures of amount of cannabis and delta-9-tetrahydrocannabinol (THC) concentration.

Setting. Ecological study with assessments at participants’ homes or in a coffee shop.

Participants. Young adult frequent cannabis users (N=106) from the Dutch Cannabis Dependence (CanDep) study.

Measurements. The objectively measured amount of cannabis per joint (dose in grams) was compared with self-reported estimates using a prompt card and average number of joints made from one gram of cannabis. In addition, objectively assessed THC concentration in the participant’s cannabis was compared with self-reported level of intoxication, subjective estimate of cannabis potency and price per gram of cannabis.

Findings. Objective estimates of doses per joint (0.07–0.88 g/joint) and cannabis potency (1.1–24.7%) varied widely. Self-reported measures of dose were imprecise, but at group level, average dose per joint was estimated accurately with the number of joints made from one gram [limit of agreement (LOA) = -0.02 g, 95% confidence interval (CI) = -0.29; 0.26], whereas the prompt card resulted in serious underestimation (LOA = 0.14 g, 95% CI = -0.10; 0.37). THC concentration in cannabis was associated with subjective potency [“average” 3.77% (P = .002) and “(very) strong” 5.13% more THC (P < .001) than “(very) mild” cannabis] and with cannabis price (about 1% increase in THC concentration per euro spent on one gram of cannabis, P < .001), but not with level of intoxication.

Conclusions. Self-report measures relating to cannabis use appear at best to be associated weakly with objective measures. Of the self-report measures, number of joints per gram, cannabis price and subjective potency have at least some validity.

Keywords. Dose, potency, quantity, self-report, THC, validation.

Peggy van der Pol, Nienke Liebregts, Ron de Graaf, Dirk J. Korf, Wim van den Brink, Margriet dan Laar

Published in Addiction (2013) 108 (10): 1801-1808
INTRODUCTION

Self-reported measures of cannabis exposure are the core of most studies investigating the negative consequences of cannabis use (e.g. dependence, psychosis, anxiety, depression [1,2]). In these studies, self-reported frequency of cannabis use (e.g. number of days using cannabis) generally serves as a proxy for exposure to delta-9-tetrahydrocannabinol (THC), the primary psychoactive constituent of cannabis. Many studies still fail to assess quantity in addition to use frequency, while this may improve estimates of total cannabis exposure considerably [3,4]. Some studies measured average number of joints on a cannabis-using day [3,5–7] or total quantity per time unit [3,4,8,9], and one study using both methods showed that number of joints per day predicted dependence more accurately than total quantity [3]. However, even with this additional quantity measure, two sources of error remain: varying doses per joint and cannabis potency levels [10]. Particularly in studies among frequent cannabis users, even relatively small errors in amount of cannabis/THC per session may result in highly inadequate estimates of the total exposure due to the process of multiplication.

Studies that consider differences in dose per joint are scarce. Korf and colleagues used two methods to estimate the dose per joint: a prompt card showing real-sized pictures of a ruler with various dosages of both herbal and resin cannabis, and number of joints made from one gram of cannabis [11]. The first method resulted in a lower dose estimate than the second. In another innovative, but labour-intensive, method participants indicated the weight of one dose of herbal cannabis using a surrogate substance (oregano) [12]. Recently, the use of surrogate substance was integrated into a time-line follow-back (TLFB) method, with good reliability and good validity [13]. However, the estimated weight of the surrogate did not correlate with the real weight of the cannabis and, therefore, this method provides only a relative measure of cannabis use. Thus, it remains uncertain how accurately cannabis users can self-report the dosage of individual joints, and which method is most reliable and valid.

As well, even with identical cannabis doses, total exposure to THC may vary considerably due to differences in potency (THC concentration). The cannabis market covers a wide range of cannabis products with a similarly wide range of potency, which varies both within and between countries [14–16]. Cannabis potency has been estimated with questions about “usual intensity of intoxication”, and this measure was associated with cannabis related health consequences independently of frequency and quantity of cannabis use [4]. Nevertheless, the association between level of intoxication and actual cannabis potency is unknown, and may be affected by individual factors such as lower intoxication reported by users who developed tolerance, using practice, the user’s physical constitution and situational factors [9]. Therefore, a subjective estimate of cannabis potency with a more direct question to categorise cannabis potency on an ordinal scale might be a better proxy for THC concentration [11]. Alternatively, retail price might be a reasonable and easy proxy for potency, as it may be a more objective indicator of THC concentration than subjective estimates of intoxication or potency. Positive correlations between THC content and price have been reported [12,14,17,18].
Overall, estimates of cannabis exposure may improve when cannabis dose and potency are considered in addition to number of days using cannabis and number of joints per day, yet the reliability and validity of these self-report measures are largely unknown [14]. With low reliability, the accuracy of self-reported dose and potency varies too much between individuals, and results of studies using these methods may be diluted. When validity is low, self-reports deviate systematically and estimates of the average total exposure are inadequate, although associations with other variables are unbiased. However, accuracy in self-reported exposure may also differ between groups. When accuracy is differential (associated with other variables in the study) this may inflate or deflate observed associations, which may lead to incorrect conclusions. For example, herbal cannabis and cannabis resin are clearly different in appearance, which may influence an individual’s estimate of dose per joint. Furthermore, subjective potency estimates may be affected by cannabis type: cannabidiol (CBD) is a psychoactive constituent of cannabis that may attenuate some effects of THC [19], but is almost absent in indoor-grown herbal cannabis [17]. Finally, cannabis dependence may affect subjective exposure estimates. Although the differential accuracy of self-reported cannabis use has never been reported, there are indications that alcohol use is underestimated in people with more drinking problems, treatment and cognitive impairment [20].

To our knowledge, the present study is the first to assess the reliability and validity of self-reported cannabis dose and potency in an ecological study using the participants’ own cannabis. Cannabis dose and potency were assessed using self-reports and objective measurements in 106 experienced young adult users from a larger prospective cohort of frequent cannabis users [21]. The first aim of this study was to validate two self-report methods to assess the dose per joint: (i) dose estimated with a prompt card and (ii) average number of joints made from one gram of cannabis. The second aim was to investigate the correlation between THC concentration established by chemical analyses and three self-report methods: (i) experienced intensity of intoxication, (ii) subjective estimate of cannabis potency and (iii) price per gram of cannabis. The third aim was to explore the moderating effect of type of cannabis (herbal versus resin) and presence of cannabis dependence on the relation between self-reported dose and potency with objective measures of cannabis exposure.

**METHODS**

**Participants and procedures**

Participants were selected from the Dutch Cannabis Dependence (CanDep) study, a prospective cohort of young adult frequent (dependent and non-dependent) cannabis users investigating predictors of cannabis dependence onset and remission [21,22]. In brief, 600 Dutch frequent cannabis users (≥3 days per week for at least 12 months) were recruited from cannabis outlets (coffee shops) and through chain referral. They were interviewed face-to-face, including detailed questions about cannabis use, and followed-up at 18 and 36 months [21]. When participants were contacted to arrange the first follow-up interview, they were informed about the validation study and
checked for eligibility. Participants for this substudy were frequent cannabis users at baseline who were still using cannabis at the time of first follow-up. On a “first-come, first-served” principle, 70 participants were included. Then, to achieve sufficient variation, recruitment was targeted at participants who were under-represented: less frequent cannabis users and those with a preference for mild cannabis types. The final result was a sample of 106 participants. Although the response rate was not recorded, only a few eligible participants declined to participate.

The study was executed immediately after the first follow-up interview and the setting was chosen by the participant, mainly their home or a coffee shop. Participants were asked to bring ≥ one gram of their commonly used cannabis, for which they were compensated financially. During the study, participants were asked questions about their cannabis consumption and the cannabis was weighed and analysed chemically.

All participants provided written informed consent before participating in the study, which was approved by a medical ethics committee.

Assessments

Self-reported dose. Two self-reported measures of dose were used. (i) Self-reported dose (in grams) was based on the comparison with a prompt card with real-sized pictures of a ruler and four dosages (0.05, 0.10, 0.20, 0.30 g) of both herbal cannabis and cannabis resin (Supporting information, Appendix S1) [11]. No dosage weights were mentioned, and intermediate options were allowed (weighted 0.03, 0.07, 0.15, 0.25, 0.40 g). (ii) In addition, dose was calculated as the inverse of the self-reported average number of joints made from one gram of cannabis (joints/ gram), to arrive at dose in grams.

Objective dose. In the Netherlands, cannabis is usually mixed with tobacco. Therefore, the participant’s cannabis sample was weighed to the hundredth gram with a pocket-sized scale [NTR-100 (Gram Precision Scales Inc.,® Mississauga, Canada) with 0.01 g accuracy ± 0.2%]. Participants were then asked to roll a joint in their habitual manner. Finally, the remainder of the sample was weighed, including unused stalk and roots, to determine the objective dose of cannabis (gram) per joint.

Self-reported potency. Three self-reported measures of potency were used. (i) The proxy intensity of intoxication during the study was assessed with a visual analogue scale ranging from 1 (light buzz) to 10 (very stoned/high). For two participants with missing values, the usual intoxication during cannabis consumption as reported during the interview was used. (ii) Participants were asked to categorise the potency of the cannabis consumed during the study as: very mild; mild; average; strong; very strong. (iii) The price paid for the total cannabis sample was reported and converted to price per gram. Four cases with missing price values were excluded from the analyses (not assessed during the interview).

THC concentration. After objective assessment of dose per joint, 0.7 g from the remaining cannabis sample was collected, put into a labelled resealable plastic bag and stored in an envelope for transport to the Trimbos Institute. Here, all samples were weighed, hermetically packed in plastic and stored in a dry dark safe at room
temperature until collective transport to the laboratory. THC and CBD analyses were performed at DSM-Resolve in concordance with the protocol of the Dutch THC monitor [17]. In brief, the samples were reduced to powder by mortar and seeds and woody parts were removed. Then two duplicate 0.05–0.10-g samples were dissolved in an organic internal standard solution. Next, herbal and resin cannabis samples were extracted ultrasonically in a two-step procedure and centrifuged. Finally, the obtained extracts were analysed using gas chromatography with flame ionisation detection (GC-FID).

**Cannabis dependence.** To explore differential accuracy, i.e. the effect of cannabis dependence on the relation between self-reported dose and potency and objective measures of cannabis exposure, 12-month DSM-IV cannabis dependence was assessed with the Composite International Diagnostic Interview (CIDI) version 3.0 [21].

**Statistical analysis**

Inaccuracy of self-reported dose is expressed as Bland & Altman’s limits-of-agreement (LOA) [23]. As such, the LOA indicates the extent of disagreement between the mean objective dose and self-reported dose, assessed with the prompt card and joints/gram. The LOA is defined as the standardised mean of the difference between all paired (subjective versus objective) ratings \([\text{mean} \pm 1.96 \times \text{standard deviation (SD)}]\). The difference between upper and lower LOAs indicates how much self-reported dose deviates from objective dose. If this difference is, for example, 0.10 g and the objective dose is 0.20 g, the self-reported dose will be \([\text{with 95\% confidence interval (CI)}]\) between 0.10 and 0.30 g. Analyses were performed in Stata version 12 (Stata Corp., College Station, TX, USA) using the “concord” command [24]. To investigate the relationship between THC concentration and self-reported potency, bivariate regression analyses were applied with subjective intoxication, experienced cannabis potency and price per gram as independent variables. Regression coefficients and standardised betas are reported: the former to interpret the relation between each of the self-reports and the objective THC concentration, the latter to establish differences in strength of associations of the various self-report measures with the objective THC concentration.

Finally, for both dose and potency, the effect of type of cannabis (herbal versus resin) on the relationship between subjective and objective cannabis exposure measures was assessed using cannabis type as an independent variable and a moderator variable (type × subjective measure potency) in the regression models. The same method was applied to explore the potential differential accuracy of cannabis dependence.

**RESULTS**

**Participants**

The sample included 78 males and 28 females with a mean age of 23.8 years (range: 19–32, SD = 3.0). In the past four weeks, participants used cannabis on 20.6 days (range: 2–28, SD = 8.0) and 2.6 joints per day (range: 1–14, SD = 2.8). During the study, 66% used herbal cannabis and 34% cannabis resin. The prevalence of cannabis dependence was 34%.
Validation of self-reported doses per joint

The objective average dose per joint was 0.26 g cannabis (range: 0.07–0.88, SD = 0.14). This was underestimated significantly with the prompt card (0.13 g; range 0.03–0.30, SD 0.07), whereas joints/gram resulted in good average estimates (0.28 g; range 0.07–1.00, SD = 0.28). Accordingly, LOAs were 0.14 g (95% CI: -0.10; 0.37) for the prompt card and -0.02 g (95% CI: -0.29; 0.26) for the joints/gram. However, the 95% CI of approximately 0.5 g in both methods indicates poor accuracy, considering the average objective dose of 0.26 g.

Validation of self-reported potency

Mean THC concentration was determined chemically at 12.4% (range: 1.1–24.7%, SD = 4.2). Mean subjective intoxication score was 5.9 on a scale from 1 to 10 (SD = 2.0). The potency distribution according to subjective categories was: 2.8% very mild, 11.3% mild, 35.9% average, 43.4% strong and 6.6% very strong. Due to small numbers in the lowest and highest categories, groups were merged into: (very) mild; average; (very) strong. Mean price per gram was 7.2 euros (range: 2.5–14.0, SD = 2.2).

Table 1 shows the associations between the objectively assessed THC concentration and the three self-report proxies for the total sample. Subjective intoxication was not correlated with THC concentration, but the subjective potency and price per gram were. Cannabis classified as “average” contained 3.77% more and cannabis classified as “(very) strong” contained 5.13% more THC than “(very) mild” cannabis, whereas with every euro spent on one gram of cannabis, THC concentration was almost 1% higher.

Cannabis type

Objective dose and potency were similar for herbal and resin cannabis, but herbal cannabis contained almost no CBD. Herbal cannabis dose was 0.28 g/joint (range: 0.07–0.77, SD = 0.13), THC concentration was 12.4% (range: 1.1–19.5, SD = 3.0) and CBD concentration was 0.2% (range: 0.0–0.5, SD = 0.1). For resin cannabis the dose was 0.23 g/joint (range: 0.17–0.89, SD = 0.15), THC 12.2% (range: 2.9–24.7, SD = 6.0) and CBD 5.4% (range: 0.2–7.9, SD = 1.5).

Table 1 Bivariate associations between objective delta-9-tetrahydrocannabinol (THC) concentration and three self-reported potency measures (N=106).

<table>
<thead>
<tr>
<th></th>
<th>b</th>
<th>95%CI</th>
<th>Beta</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Level of intoxication 1-10</td>
<td>0.16</td>
<td>[-0.24,0.57]</td>
<td>0.16</td>
<td>.42</td>
</tr>
<tr>
<td>2. Subjective potency estimate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Very) Mild Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3.77</td>
<td>[1.40,6.14]</td>
<td>0.43</td>
<td>.002</td>
</tr>
<tr>
<td>(Very) Strong</td>
<td>5.13</td>
<td>[2.86,7.41]</td>
<td>0.61</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3. Price in Euro’s per gram*</td>
<td>0.94</td>
<td>[0.60,1.28]</td>
<td>0.48</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

CI = confidence interval; b = regression coefficients; beta: standardised beta. *N=102.
Table 2 shows that the accuracy of both self-reported dose measures was independent of cannabis type, as type did not moderate significantly the association between self-reported and objective dose. However, Table 2 also shows that the relationship between all self-reported potency measures and THC concentration was modified by cannabis type, with significant correlations between subjective measures of potency and THC concentration only in resin users, and not in herbal users (see also Figure 1).

Table 2: Associations between objective and self-reported dose and potency measures, moderated by cannabis type (N=106).

<table>
<thead>
<tr>
<th></th>
<th>Self-reported dose/potency</th>
<th>Resin (N=36)</th>
<th>Self-report x type interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>1. Prompt card</td>
<td>0.91</td>
<td>&lt;.001</td>
<td>-0.03</td>
</tr>
<tr>
<td>2. Joints/gram a</td>
<td>0.42</td>
<td>&lt;.001</td>
<td>-0.14</td>
</tr>
<tr>
<td>3. Intoxication 1-10</td>
<td>-0.22</td>
<td>.33</td>
<td>-8.99</td>
</tr>
<tr>
<td>4. Subjective potency estimate (Very) Mild Reference</td>
<td>-2.79</td>
<td>.24</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.93</td>
<td>.39</td>
<td>1.55</td>
</tr>
<tr>
<td>(Very) Strong</td>
<td>1.75</td>
<td>.42</td>
<td>7.88</td>
</tr>
<tr>
<td>5. Price per gram b</td>
<td>0.45</td>
<td>.11</td>
<td>-5.52</td>
</tr>
</tbody>
</table>

Herbal (N=70), resin (N=36). b: regression coefficient. a Two extreme values (excluded in the sensitivity analyses) were responsible for this borderline significant (P = .08) moderation effect of cannabis type. b N=102: herbal N=67; resin N=35.

**Cannabis dependence**

Similar analyses were used to explore the possibility of cannabis dependence moderating the association between subjective and objective indicators of cannabis exposure. It should be noted, however, that this was not the main aim of the current study, and power to detect differential accuracy was limited. For the prompt card, there was a trend towards a greater underestimated dose in dependent users, in addition to the systematic underestimation by this method. No such moderation was found for the other self-report methods (data available in the Supporting information, Appendix S1).

**Post-hoc sensitivity analyses**

Two participants reported extremely high objective doses (i.e. values > 1.5 times the interquartile range). These may have had a disproportionate effect on our results, and were therefore excluded in post-hoc sensitivity analyses. This indeed narrowed the LOAs for the prompt card from 0.14 (95% CI -0.10; 0.37) to 0.13 g (95% CI -0.04; 0.19) and for the joints/gram from -0.02 (95% CI -0.29; 0.26) to -0.03 g (95% CI -0.25; 0.20). However, these improved LOA ranges were still considerable: 0.23 and 0.45 g, respectively.
Figure 1 Correlation between objective delta-9-tetrahydrocannabinol (THC) concentration and three self-reported potency measures: (1) intensity of intoxication, (2) subjective potency, and (3) price.

**DISCUSSION**

Including self-report measures of cannabis dose and potency may produce more accurate estimates of cannabis and THC exposure than only number of days using cannabis and joints per day [10]. To our knowledge, this is the first study to investigate the reliability...
and validity of self-reported measures of both dose and potency in an ecological study, i.e. using cannabis provided by participants to determine objective dose and potency.

**Self-reported dose**

We found a very wide range in the dose per joint, with a more than 10-fold difference between lowest and highest dose 0.07–0.88 g/joint). This finding confirms the need to consider dose per joint when assessing cannabis exposure. Unfortunately, we also found that both self-report dose measures were imprecise and inaccurate. It should be noted, however, that the joints/gram method resulted in an accurate estimation of the average dose per joint, whereas the prompt card resulted in a serious underestimation. Nevertheless, the correlations between objective dose and self-reported proxies found in the current study were too low for implementation in studies relating subjective estimates of individual cannabis exposure to individual health outcomes.

Whereas cannabis users may simply be unable to self-report doses of individual joints, the notable variation in doses per joint supports further efforts to improve these self-report measures. As the average dose estimated from the joints/gram was accurate, using an extra decimal may improve the accuracy of individual self-reported doses. This may be even more important when other methods of cannabis consumption (e.g. joint, pipe, blunt) are assessed: doses in blunts or pipes are possibly higher than in joints [9,12], and the joints/gram method is less sensitive with higher doses (difference between one and two joints is 0.50 g and between three and four joints is 0.08 g). Although mixing cannabis with tobacco in a joint is common in the Netherlands and most other European countries, this may limit extrapolation of our results to (countries with) other consumer practices. The precision of the dose per joint method may also be overestimated, because Dutch coffee shops usually weigh cannabis before it is sold. Therefore, Dutch cannabis users may be more aware of cannabis quantities than users from countries with non-tolerated sales. As a “street gram” is often a little light of a gram [25], fewer joints could be made from a “gram”, leading to an overestimated dose per joint. In those cases, the use of surrogate cannabis as implemented in the TLFB method may be preferable [13]. However, when this method proves unfeasible, an improved version of the prompt card method could be used, such as another visual reference in addition to the ruler (e.g. a credit card or cigarette paper) or improvements inspired by nutritional research investigating self-reported portion sizes [26].

Finally, the tendency towards an even stronger underestimation of the dose with the prompt card in dependent users warrants further investigation. If such an interaction really exists, associations between cannabis exposure and dependency problems would be underestimated and weaker associations may be missed. Also, even when self-report dose measures improve, other sources of imprecision remain, including (varying doses in case of) sharing of joints in social contexts and differences in internal exposure because of variations in smoking behaviour (“smoking topography”).
**Self-reported potency**

The current study showed a significant correlation of objective THC concentration with potency estimates and price per gram, but not with self-reported level of intoxication. Too few participants categorised their cannabis as very mild or very strong to assess them separately, and the difference in THC concentration between average (3.77%) and (very) strong cannabis (5.13%) was relatively small; therefore, a dimensional approach may be preferable. The correlation between price per gram and cannabis potency suggests that some value is placed on perceived higher potency cannabis (by both sellers and consumers). However, the limitations of this method should be mentioned. First, the unstable correlation between price and potency over time may hinder comparisons over time. In the Netherlands, cannabis prices have increased while THC concentrations have remained somewhat stable since 2005 [27]. While 92.5% of our population usually buys cannabis in coffee shops with official maximum sales of five grams, limitations such as cheaper bulky purchases should be considered in other countries. More generally, it should be noted that even when users always buy the same type of cannabis from the same coffee shop (or dealer), the THC concentration may vary. A pilot study suggests that this range may approximate 5% in samples of the same type purchased on the same day [28]. This may partly explain the inaccuracy of self-reported potency, and should be considered when self-reported potency estimates are assessed.

Although self-reported potency estimates were more accurate for resin than for herbal cannabis, they were still unsatisfactory. The more accurate association between self-reported potency and THC concentration for resin users cannot be explained by differences in CBD levels, which are higher in resin compared to herbal cannabis (which contains practically no CBD). CBD would attenuate the subjective effects of THC and thus result in lower overall subjective scores, while mean subjective potency scores were, in fact, higher for resin than for herbal cannabis in the high THC ranges (Fig. 1). A more likely explanation is that, even though THC ranges were similar in both cannabis types, most herbal cannabis samples were moderate to strong. Very few herbal samples had high or low THC concentrations: 70% of the herbal cannabis samples contained between 10.1 and 15.0% THC (15th and 85th percentiles) versus 5.1–20.3% in resin. The lack of variation in THC concentrations in herbal cannabis may be a plausible cause of the poorer association with self-reported potency compared to resin.

Finally, the participants in this study were drawn from a larger pool of frequent (baseline ≥3 days per week) cannabis users. This may have led to an overestimation of precision, as these users are more experienced than less frequent users in estimating cannabis dose and potency. However, frequent users may also trivialise, and thus underestimate their cannabis use compared to less frequent users. Regardless, the net effect of dose and potency are most eminent in frequent users, and thus the current sample was an appropriate population to investigate the validity of self-reports other than frequency of use.

**Conclusions**

The investigated self-reported measures of dose and potency are not precise and not accurate enough to be implemented in future studies. Given the need for more
precise cannabis exposure measurement, self-reported measures should be improved and compared internationally with regard to potential bias. Meanwhile, in a situation where most studies do not allow for the objective assessment of dose or potency of the cannabis consumed by individual users, self-reported number of joints per gram (group level) and cannabis price (individual level) are among the least problematic options.

ACKNOWLEDGEMENTS

We acknowledge Sander Rigter of the Dutch THC monitor for assistance in the cannabis sample processing and Tibor Brunt for his valuable remarks on a previous version of this manuscript.

REFERENCES


SUPPORTING INFORMATION

Additional Supporting Information may be found in Appendix S1: Exploration of moderation of accuracy by the presence of cannabis dependence.
APPENDIX S1
EXPLORATION OF MODERATION OF ACCURACY BY THE PRESENCE OF CANNABIS DEPENDENCE
INTRODUCTION

Estimates of cannabis exposure may improve when information regarding dose and potency are taken into account in addition to the number of days using cannabis and/or the number of joints per day. Although several self-report measures are available, validity and reliability of these measures is mostly unknown. Systematic errors may artificially inflate or deflate the observed associations in studies using these self-report measures, when they are correlated with other variables under investigation. To explore the possibility and direction of such correlations, the effect of cannabis dependence on the relation between self-reports and objective measures of cannabis dose and potency was assessed.

Current cannabis dependence (N=36) was included as moderator variable (dependence×self-reported dose/potency) in linear regression models of the objective dose/potency. It should be noted, however, that the main aim of the validation study was to assess reliability and validity of these measures, and that power to detect differential accuracy for subjects with and without cannabis dependence was limited.

RESULTS

With regard to dose, the trend of moderation by dependence suggests the possibility of differential accuracy for the prompt card method (Table S1). Overall, the prompt card underestimates the objective dose. The moderating trend indicates that this underestimation may be larger among people who are dependent (Table S1 and Figure S2). According to this model, for every one gram increase in objective dose, the additional underestimation in dependent users is 0.40 gram. As the average objective dose was 0.26 gram cannabis (range: 0.07-0.88), the average additional underestimation would approximate 0.1 gram per joint according to this model. No moderation effects were observed for the self-reported number of joints per gram (Table S1).

Table S1 Bivariate associations between self-reported and objective dose/potency moderated by cannabis dependence (N=106).

<table>
<thead>
<tr>
<th></th>
<th>Self-report</th>
<th>Dependence (N=36)</th>
<th>Interaction self-report x Dependence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>P</td>
<td>b</td>
</tr>
<tr>
<td>1. Prompt card</td>
<td>0.89</td>
<td>&lt;.001</td>
<td>-0.03</td>
</tr>
<tr>
<td>2. Joints/gram</td>
<td>0.55</td>
<td>&lt;.001</td>
<td>0.02</td>
</tr>
<tr>
<td>3. Intoxication 1-10</td>
<td>0.02</td>
<td>.94</td>
<td>-1.96</td>
</tr>
<tr>
<td>5. Price per gram</td>
<td>1.02</td>
<td>&lt;.001</td>
<td>2.29</td>
</tr>
</tbody>
</table>

b=regression coefficient. Outliers (>1.5 times the interquartile range) were excluded: self-reported dose based on prompt card (N=104), and number of joints made from one gram (N=103). *missing values (N=102).
With regard to potency, no tendencies of moderation was found. It should be noted however, that outliers were excluded in these analyses and that only trends and no statistically significant moderation was found (Table S1 and Figure S3).

**IMPLICATIONS**

The findings presented in Van der Pol 2013 et al. underscore both the need for more precise cannabis exposure measurement, and the considerable inaccuracy of the investigated self-report measures of dose and potency. The results presented in this supplement stress the importance to consider differential inaccuracy when such self-report measures are further developed and tested.
Figure S1 Full colour prompt card showing various herbal and resin cannabis doses. No dosage weights were mentioned on the prompt card. Doses: A=0.05; B=0.10; C=0.20; D=0.30 gram. Intermediate options were weighted: <A=0.03; >A<B=0.07; >B<C=0.15; >C<D=0.25; >D=0.40 gram. Real size prompt card available online.
Figure S2 Association between objective dose and self-reported prompt card (1a-1c) and joints per gram (2a-2c) dose, moderated by cannabis type and cannabis dependence. 

Outliers (>1.5 times the interquartile range) were excluded: self-reported dose based on prompt card (N=104), and number of joints made from one gram (N=103). Resin users (N=36), dependent users (N=36).
Figure S3. Association between objective THC concentration and self-reported intoxication (1a-1c), potency estimate (2a-2c), and price per gram (3a-3c), moderated by cannabis type and cannabis dependence. Resin users (N=36), dependent users (N=36).