Estimating Cannabis Consumption in Milligrams of THC From Self-Reported Hit Size

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ABSTRACT

Objective: Estimating delta-9 tetrahydrocannabinol (mgTHC) using hits involves converting hits to grams via a grams-per-hit ratio (GPHR). Previous studies assumed a single hit size (SHS), ignoring individual hit size variations. This study investigates a multiple qualitative hit size (MQHS) approach based on self-reported hit sizes (small, medium, large) to improve mgTHC estimates. **Method:** Adults (N = 1,824) who used cannabis in the past week completed an online survey on cannabis consumption, reporting quantities in hits and grams, and estimating their hit sizes. We calculated mgTHC using both SHS (0.06g/hit for flower, 0.012g/hit for concentrate) and MQHS. For the MQHS approach, we calculated median GPHRs for each hit size group and assigned those medians to individuals within that group. **Results:** For flower, median GPHR increased with hit size (small: 0.042, medium: 0.062, large: 0.093). The MQHS estimate for mgTHC from flower was higher than SHS for large hits (95% CI:[12.4, 50.0]) but showed no difference for medium or small hits (95% CI: [-3.2, 8.1]; 95%CI: [-27.6, 3.4]). For concentrate, median GPHR was similar for small and medium hits but lower than large hits (small: 0.024, medium: 0.025, large: 0.035). MQHS estimates for mgTHC were higher than SHS for all hit sizes (95% CI: [46.3, 86.3]; 95% CI: [24.8, 45.5]; 95% CI: [11.5, 36.5] for large, medium, small hits, respectively). **Conclusions:** The MQHS estimates captures hit size variability for flower. The floor effect with median GPHRs for concentrates suggests further investigation is needed for MQHS estimates with concentrates. The MQHS approach illustrates a method to develop new standard GPHRs for each qualitative hit size group, after further investigation.

Key words: = THC exposure; cannabis quantification methods; cannabis, estimation; THC dosing

Cannabis use is gaining popularity in the United States, and the diversity of cannabis products continues to grow with changing cannabis laws (Davenport, 2021; Hall & Lynskey, 2020; Spindle et al., 2019). Δ9-tetrahydrocannabinol (THC) is a major psychoactive cannabinoid in most cannabis products that can cause intoxication and behavioral impairment related to the amount consumed (Compton et al., 2019; Rajapaksha et al., 2020). Similarly, potential therapeutic benefits of cannabis products may be related to dosing effects. Understanding how much THC individuals consume is important to both limit adverse effects and maximize potentials benefits of cannabis use. Yet, with the vast variety of

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products on the market, it is difficult to standardize the measurement of THC consumption across multiple product types (i.e., edibles, flower, concentrates, etc.).

Accurately estimating THC consumption in real-world settings is difficult due to multiple factors. Many cannabis products do not have adequate labels that indicate milligrams of THC (mgTHC) per product/serving. For instance, the most commonly used products, cannabis flower and concentrate, might not be labeled, and those that are may only list the potency (%THC) and product weight rather than the total amount of mgTHC in the product (Davenport, 2021). Translating potency and weight to mgTHG consumed requires additional information about 1) the quantity of product that was consumed (i.e., how many grams were loaded in the pipe/joint or how many hits/puffs were taken) and 2) the method of administration to account for any THC that is lost while consuming the product (i.e., side smoke, pyrolysis, etc.).

Prior Work Quantifying mgTHC

Our group has been working towards a solution to quantify THC consumption across multiple routes of administration and product types. An initial study on smoked and vaped products indicated that consumers showed preferences for how they estimated the amount of cannabis consumed; 55% vs. 45% selected to report in number of grams and hits, respectively (Borodovsky et al., 2023). Allowing a choice of how to report amounts consumed reduces cognitive burden and likely increases accuracy. To estimate mgTHC for those reporting in number of grams (Formula 1), we multiplied the number of grams of product by the potency of product and then adjusted for lost THC during the consumption process, using the method of administration efficiency constant (MAEC; Budney et al., 2022).

Formula 1

$$mgTHC = Number\ of\ grams\ of\ product * Potency\ of\ product\ (\%THC) * MAEC$$

For those reporting in hits, we converted the number of hits into the number of grams using a grams-per-hit ratio (GPHR) derived from prior lab studies (Formula 2). After converting hits to grams, we calculated mgTHC by multiplying the derived grams value by the potency of product and applied the MAEC adjustment. In this hits-to-grams model, the accuracy or validity of the GPHR substantially impacts the precision of the mgTHC estimate.

Formula 2

$$mgTHC = Number\ of\ hits\ of\ product * GPHR * Potency\ of\ product\ (\%THC) * MAEC$$

Grams-per-hit Ratios (GPHR)

No consensus for an appropriate GPHR is available. In our initial study and in two other published studies, a single GPHR drawn from human lab studies was used for all participants (Borodovsky et al., 2022; Budney et al., 2022; Lynch et al., 2021; McClure et al., 2012; Varlet et al., 2016). This single GPHR assumes all participants have the same single hit size (SHS). An SHS GPHR could potentially provide a reasonable estimate among all cannabis consumers, as it represents an average value across a multitude of cannabis consumers. However, prior studies clearly demonstrate that consumers inhale hits that vary substantially in size and across product types (Heishman et al., 1989; Matthias et al., 1996; McClure et al., 2012). Thus, an SHS GPHR could substantially overestimate or underestimate mgTHC consumption for many consumers.

To better estimate individual use, we developed two methods to capture individual hit size (Borodovsky et al., 2023). The first approach required two survey items asking participants to report their consumption in both the number of hits and grams, regardless of the preferred unit. Individual GPHRs were calculated by dividing the grams of product consumed per day by the hits of product per day. The second approach used one survey item asking participants how many hits it would take them to finish a half gram of flower or concentrate using their preferred method of administration. Their individual GPHR was

calculated by dividing a half gram by the estimated number of hits. A within-subject comparison of these two approaches found that regardless of product type or GPHR approach, 45% of participants had an individual GPHR that was 50% larger or smaller than the SHS GPHR used in the initial study. While both individual approaches addressed the variability in hit size, both also required individuals to think about their consumption in number of grams, which can be potentially challenging, given that many cannabis consumers struggle to accurately estimate small quantities of cannabis in grams (Prince et al., 2018). Such contemplation increases cognitive burden and likely decreases the accuracy of mgTHC among those who prefer to report their use in number of hits.

The Current Study

To further reduce burden without sacrificing accuracy, we sought to develop a GPHR approach that accounted for multiple qualitative hit sizes (MQHS) and allowed those who prefer the hits unit to estimate their use by only thinking about hits. This MQHS approach requires asking one qualitative hit size survey question: "*When you smoke or vape, do you take a small, medium, or large hit?*" The present study illustrates a method to generate and establish standard MQHS GPHRs for those who report taking small, medium, or large hits, and then compares mgTHC estimates derived using the MQHS GPHR approach with estimates calculated using the SHS GPHRs. If standard MQHS GPHRs can be established and validated, future studies that require mgTHC estimates would only need to include this single MQHS item to obtain a GPHR for those who prefer to report in hits.

METHODS

Sample Recruitment and Sample Size

This study is part of a larger study detailed elsewhere (Borodovsky et al., 2023). Adults 18+ were recruited using Facebook and Instagram advertising with cannabis related key-word targeting (Borodovsky et al., 2018). Those who clicked on the advertisement were redirected to the survey consent page hosted on Qualtrics (Qualtrics, Provo, UT). Participants were recruited between June 1 - July 9, 2022. The Dartmouth Committee for Protection of Human Subjects approved all study procedures. No compensation was provided for participation.

A total of n = 3,658 clicked on the advertisement link, of whom 39 were ineligible (i.e., 4 were less than 18 years old, 35 were potentially bots). Among those who consented and were eligible, 812 were excluded due to inconsistent responding. Of the remaining n = 2,807, 447 were excluded for not using flower or concentrate products in the past week, and 536 were excluded for not providing all necessary items to calculate milligrams of THC. The final analytic sample size was N= 1,824.

Survey Items and Design

The survey consisted of 59 items, designed based on prior literature (Borodovsky et al., 2018; Cuttler & Spradlin, 2017; Sikorski et al., 2021) and included data quality checks, such as reCAPTCHA, bot-only items, and attention checks. Additionally, the survey queried sociodemographics, past 30- and past 7-day frequency, and methods of administration (smoking flower, vaping flower, vaping concentrate, dabbing concentrate, edibles, liquids/tinctures, and capsules).

All participants reported their past-week flower and concentrate consumption both in the number of hits and grams of product. To control for ordering effects, participants were randomized with equal probabilities to either report number of hits first (n = 912) or report number of grams first (n = 912).

Consumption quantity. Participants were initially asked if they used the same amount of product on each day they used for flower and concentrates, separately. Those who used the same amount were asked to estimate their typical number of hits and grams of flower and/or concentrate used per time-of-day quadrant (morning 6AM – 12PM, afternoon 12PM – 4PM, evening 4PM – 8PM, night 8PM – 6AM). Those who did not use the same amount were asked for the number of hits/grams of flower and concentrate per time-of-day quadrant for their most recent day of use. Response options for number of hits of both flower and concentrate were 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11-15, 16-20, 21-25, 26-30, over 30 hits. For calculation of mgTHC, midpoints were used for ranges (i.e., if participant selected 16-20 hits, we

used 18 hits in the formula). Response options for number of grams of flower and concentrate were: 1/16, 1/8, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 1 3/4, 2, Over 2g. More details can be found elsewhere (Borodovsky et al., 2022).

Potency. Participants reported their product potency (%THC) using a sliding scale. The survey assessed the potency of flower, prefilled THC cartridges, and other concentrates (e.g., oils, wax, shatter, etc.). Flower potency ranged from 0% to 30% THC. Both prefilled THC cartridge and other concentrate potency options ranged from 40% to 100% THC.

Qualitative hit size. Participants were asked to report their estimated hit size for their flower and concentrate use. Response options were "Small hit,", "Medium hit," and "Large hit," and included the following statement in the instructions: *"A large hit would be the amount of air you inhale to hold your breath for as long as possible."*

GPHR Approaches

Single hit size (SHS). GPHRs were derived from the average number of grams consumed per hit as described in lab-based research studies. The final assumptions of the averages being one hit of flower results in consumption of 0.06g of the product (GPHR for flower = 0.06g), and one hit of concentrate results in 0.012g of concentrate product being consumed (GPHR for concentrate = 0.012g (Budney et al., 2022; Lynch et al., 2021; McClure et al., 2012; Varlet et al., 2016).

Multiple qualitative hit sizes (MQHS). GPHRs that correspond to small, medium, or large hit sizes were determined as follows: each participant's individual GPHR was first calculated by dividing the number of grams consumed per day by the number of hits taken per day. Median GPHRs were then calculated separately for participants that reported small, medium, or large hit sizes, respectively. Each participant who reported a small hit size was assigned the small hit size median GPHR, those reporting medium hit size were assigned the medium hit size GPHR, and so forth. This procedure was followed for both flower and concentrate products.

Calculating Milligrams of THC

To calculate milligrams of THC (mgTHC), we used Formula 2 described above. Two mgTHC estimates were obtained for each participant: one using the SHS GPHR (formula 3) and one using the MQHS GPHR (formula 4), with the only difference being the GPHR constant.

Formula 3.

$$mgTHC = Number\ of\ hits\ of\ product * SHS\ GPHR * Potency\ of\ product\ (\%THC) * MAEC$$

Formula 4.

$$mgTHC = Number\ of\ hits\ of\ product * MQHS\ GPHR * Potency\ of\ product\ (\%THC) * MAEC$$

Data Analysis

Quantile regressions compared the median individual GPHRs across the three MQHS groups for both flower and concentrate products. Quantile regressions then compared the mgTHC estimates derived from the SHS and MQHS approaches for overall consumption from flower products and for each MQHS group, and the same was performed for concentrate products. All regressions included cluster-robust standard errors and were controlled for the order of items. Analyses were conducted using STATA version 16.1. All distributions are described using medians, as the distributions were skewed.

RESULTS

Sample Demographics

The sample had a mean age of 39.1 (*SD* = 16.2) years and was 80.0% non-Hispanic White. The sample was 48.2% female, 50.6% were employed full time, and 55.1% completed an Associate's degree or higher education. Full sample demographics have been previously published (Borodovsky et al., 2023).

Cannabis Use Characteristics

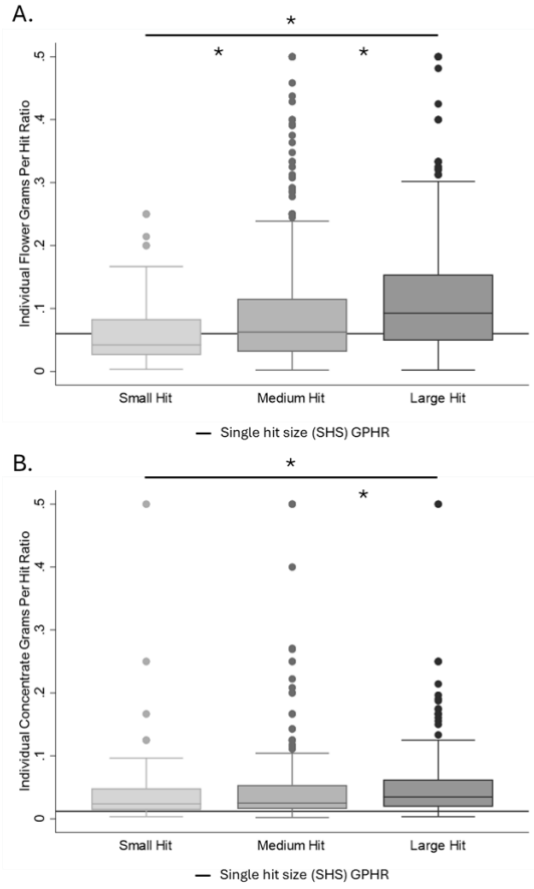
The average age of cannabis use onset was 16.5 (*SD* = 4.7) years. The sample was composed of primarily frequent and heavy consumers with

participants using on average 26.3 (*SD* = 7.1) days in the past month and 6.3 (*SD* = 1.6) days in the past week. Smoking flower was the most common method of administration (90.8%), followed by vaping concentrate (42.2%), vaping flower (20.7%), and dabbing concentrate (18.3%). The most common method used to smoke flower was joints (37.2%), and the most common method for using concentrate was prefilled cannabis cartridge (66.9%). Additionally, 50.7% reported using either edibles, capsules, liquids, or another method. Nearly 71.2% reported using 2 or more methods of administration. The median number of hits of flower per day was 14 (Q1: 7, Q3: 29), and the median number of hits of concentrate per day was 7 (Q1: 4, Q3: 14). The median number of grams of flower per day was 1 (Q1: 0.4, Q3: 2.3), and the median number of grams of concentrate per day was 0.2 (Q1: 0.1, Q3: 0.4).

Individual GPHRs Among MQHS Groups

Descriptive statistics can be seen in Table 1. The median flower GPHR for those who reported taking small (*n* = 304), medium (*n* = 2,252), and large (*n* = 827) hits was 0.042g/hit, 0.062g/hit and 0.093g/hit respectively. Of note, the SHS GPHR (0.06) was very similar to the median GPHR among the medium hit size group. As shown in Figure 1a, participants reporting a large hit size for flower had a greater first quantile, median, and third quantile GPHR than those reporting a medium (Q1: 0.013, 95%CI: [0.006, 0.021]; Q2: 0.028, [95%CI: 0.016, 0.041]; Q3: 0.041, 95%CI: [0.027, 0.056]) or a small hit size (Q1: 0.021, 95%CI: [0.013, 0.029]; Q2: 0.042, [95%CI: 0.028, 0.057]; Q3: 0.068, 95%CI: [0.051, 0.086]). Those reporting a medium hit size had a greater first quantile, median, and third quantile GPHR for flower than those reporting a small hit (Q1: 0.008, 95%CI: [0.003, 0.013]; Q2: 0.014, 95%CI: [0.005, 0.023]; Q3: 0.027, 95%CI: [0.012, 0.041]).

Figures 1A & 1B. *Individual Flower Grams-Per-Hit Ratios (GPHRs) for Each Participant Grouped by Self-Reported Hit Size; Individual Concentrate Grams-Per-Hit Ratios (GPHRs) For Each Participant Grouped by Self-Reported Hit Size.*



Note. A: The median GPHRs for each hit size group is the GPHR assigned to each hit size group for the multiple qualitative hit size (MQHS) GPHR approach. The single hit size (SHS) GPHR approach contains only one GPHR (0.06) and is represented to allow comparisons between the GPHRs in the MQHS and SHS approaches. * denotes significant difference. B: Individual concentrate grams-per-hit ratios (GPHRs) for each participant grouped by self-reported hit size. The median GPHRs for each hit size group is the GPHR assigned to each hit size group for the multiple qualitative hit size (MQHS) GPHR approach. The single hit size (SHS) GPHR approach contains only one GPHR (0.06) and is represented to allow comparisons between the GPHRs in the MQHS and SHS approaches. * denotes significant differences.

Table 1. *Descriptive Statistics for Individual Grams-Per-Hit Ratios and Milligrams of THC Estimates*

	Mean	SD	Min	Q1	Median	Q3	Max	Skewness	Kurtosis
Individual Flower GPHR	0.10	0.14	0.00	0.03	0.07	0.13	3.50	12.62	272.27
Individual Concentrate GPHR	0.05	0.07	0.00	0.02	0.03	0.06	0.90	5.93	53.31
Single Hit Size (SHS) Estimates									
mgTHC per Day	117.97	147.97	1.80	32.34	68.04	144.18	1775.52	3.48	22.60
mgTHC from Flower	97.25	119.85	1.80	27.00	54.00	115.74	972.00	2.88	13.41
mgTHC from Concentrate	58.00	80.12	2.12	15.30	32.94	67.20	803.52	4.14	27.48
Multiple Qualitative Hit Size (MQHS) Estimates									
mgTHC per Day	169.88	248.65	1.26	39.55	91.51	198.47	3081.00	4.58	35.44
mgTHC from Flower	113.51	153.67	1.26	29.14	61.60	138.31	1276.50	3.42	18.02
mgTHC from Concentrate	137.02	200.61	4.20	32.80	75.79	150.00	2082.00	4.17	26.96

Note. THC = delta-9 tetrahydrocannabinol

For concentrates, the median GPHRs for those selecting small (n = 471), medium (n = 849), and large (n = 349) hits were 0.024g/hit, 0.025g/hit, and 0.035g/hit, respectively. The GPHR for each MQHS group was larger than the SHS GPHR (0.012). As seen in Figure 1b, those reporting a large hit size had a greater median GPHR than those reporting a medium hit size (Q2: 0.008, 95%CI: [0.002, 0.014[), but the GPHR did not differ significantly at the first or third quantile (Q1: 0.002, 95%CI: [-0.001, 0.006]; Q3:0.009, 95%CI: [-0.001, 0.019]). Those reporting a large hit size had a greater first quantile, median, and third quantile GPHR than those reporting a small hit size (Q1: 0.005, 95%CI: [0.001, 0.010]; Q2: 0.010, 95%CI: [0.003, 0.016]; Q3: 0.016, 95%CI: [0.001, 0.031]). The GPHR for those reporting a medium or a small hit size did not differ significantly at any quantile (Q1: 0.003, 95%CI: [-0.0003, 0.006]; Q2: 0.002, 95%CI: [-0.007, 0.003]; Q3: 0.006, 95%CI: [-0.008, 0.020]).

MQHS vs. SHS Approach for Calculating mgTHC

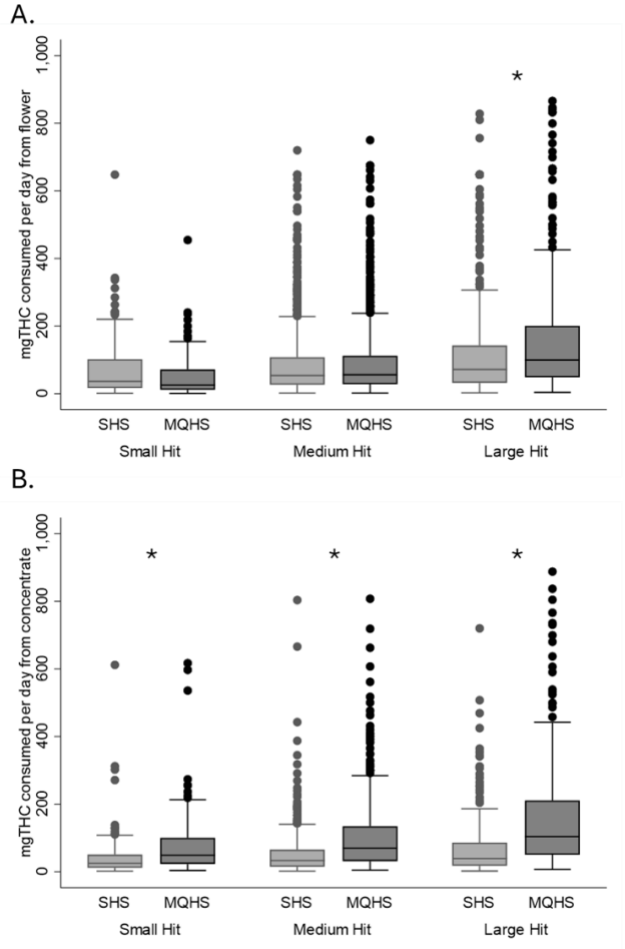
The overall median mgTHC per day estimate for all participants was greater with the MQHS GPHR approach than with the SHS approach (92.6mg vs 68.0mg respectively; Q2: 22.5, 95%CI: [14.8, 30.2]). The mgTHC per day estimate for all participants was also greater at the first and third quantile with the MQHS GPHR approach than the SHS approach (Q1:7.6, 95%CI: [3.9, 11.3]; Q3: 56.2 95%CI: [49.3, 73.0]).

Flower. Comparisons of mgTHC estimates from flower products resulted in greater overall estimates from the MQHS approach than the SHS approach at the median and third quantile, but not the first quantile (Medians: 60.4mg vs 54mg; Q1: 1.6 95%CI: [-1.1, 4.3]; Q2: 6.5 95%CI: [0.9, 12.1]; Q3: 16.5, 95%CI: [3.8, 29.2]). Separate comparisons by MQHS groups showed that among those reporting a large hit size, the MQHS approach produced greater estimates of mgTHC than the SHS approach: 99.9mg vs 72.0mg; Q1: 15.4 95%CI: [5.9, 24.9]; Q2: 31.2, 95%CI: [12.4, 50.0]; Q3: 56.2 95%CI: [23.9, 88.5] (Figure 2a). No differences between the MQHS and SHS approaches in mgTHC were observed among the

medium hit size group (56.3mg vs 54mg; Q1: 1.2, 95%CI: [-1.6, 4.1]; Q2: 2.4, 95%CI: [-3.2, 8.1]; Q3: 5.3, 95%CI: [-8.4, 18.9]) or at the median and third quantile for the small hit size group (25.5mg vs 36.6mg; Q2: -12.1, 95%CI: [-27.6, 3.4]; Q3:-30.2, 95%CI: [-74.2, 13.8]), but there were significant differences at the first quantile for the small hit size group (Q1: -5.4, 95%CI: [-9.4, -1.3]).

Concentrates. Comparisons of mgTHC estimates from concentrate products resulted in greater overall estimates from the MQHS than the SHS approach (73.9mg vs 32.9mg; Q1: 17.2, 95%CI: [13.9, 20.6]; Q2: 39.9, 95%CI: [31.8, 48.0]; Q3: 79.5, 95%CI: [65.3, 93.7]). For each of the three MQHS groups, the MQHS approach produced larger estimates of mgTHC than the SHS approach (Figure 2b; 104.1mg vs 39.1mg; Q1: 11.4, 95%CI: [6.2, 16.5]; Q2: 66.3, 95%CI: [46.3, 86.3]; Q3: 45.7, 95%CI: [19.0, 72.3]; 70mg vs 33.8mg; Q1: 16.0, 95%CI: [11.1, 20.9]; Q2: 35.1, 95%CI: [24.8, 45.5]; Q3: 67.9, 95%CI: [50.6, 85.2]; 49.8mg vs 25.2mg; Q1: 32.4, 95%CI: [21.1, 43.9]; Q2: 24.0, 95%CI: [11.5, 36.5]; Q3: 125.7, 95%CI: [77.8, 173.6] for the large, medium, and small hit size groups, respectively).

Figures 2A and 2B. *Estimates of Milligrams of THC (mgTHC) Consumed From Flower and Concentrates; Grouped by Grams-Per-Hit Ratio Approach and Qualitative Hit Size*



Note. A: Estimates of mgTHC consumed from only flower products using both the single hit size approach (SHS) and the multiple qualitative hit size approach (MQHS) among each self-reported hit size group (small, medium, large). * denotes significant differences between the SHS and MHs approaches. B: Estimates of mgTHC consumed from only concentrate products using both the single hit size approach (SHS) and the multiple qualitative hit size approach (MQHS) among each self-reported hit size group (small, medium, large). * denotes significant differences between the SHS and MHs approaches.

DISCUSSION

These findings contribute to the ongoing development of survey methods for increasing the accuracy of estimating mgTHC consumption. The present study illustrates a novel, low-burden method of personalizing grams-per-hit ratios (GPHRs) to account for varying hit sizes (i.e., small, medium, large) when calculating mgTHC among cannabis consumers who report their consumption in hits/puffs/tokes. This novel MQHS GPHR approach accounts for some of the variability in hit size among cannabis consumers, which in turn improves the accuracy of the mgTHC estimate compared to using a single GPHR for all consumers. The method used in this study to derive MQHS GPHRs provides a roadmap for developing standard constants for the MQHS approach that will allow researchers to ask only one question (i.e., "*Do you take a small, medium, or large sized hit?*") to determine an individual's GPHR when calculating mgTHC. Improving mgTHC estimation methods is crucial for precise prevention messaging, assessing cannabis policy impact, and evaluating clinical trial outcomes on cannabis efficacy and adverse reactions.

Results showed that GPHRs, derived by dividing self-reported grams consumed per day by hits per day, differed among groups who reported taking low, medium, or large sized hits. This supports observations from laboratory studies that documented individual differences in hit size when cannabis is smoked or vaped. (Heishman et al., 1989; Matthias et al., 1996; McClure et al., 2012) For flower products, the GPHRs for the three hit size groups clearly differed from each other, suggesting strong potential for developing standardized MQHS GPHRs for calculating mgTHC from self-reported number of hits of flower products. The MQHS and SHS approaches produced similar mgTHC estimates for those who reported medium-sized hits, as the GPHR for the medium hit size group in the MQHS approach (0.062) was similar to the SHS GPHR (0.06). This observation supports the MQHS approach, given that the medium hit size likely approximates our sample's average and the SHS GPHR value represents the average hit size across laboratory studies. For those who reported taking large-sized hits, the MQHS approach produced a greater mgTHC estimate than the SHS approach, likely reflecting more valid individual estimates, as hit size impacts the amount of THC consumed. (Azorlosa et al., 1995) We did not observe a significant difference among those reporting small hits (i.e., less mgTHC with the MQHS approach), although values were in the expected direction. Limited low-end response options for reporting grams per day and difficulty estimating small quantities of flower may have contributed to this null finding. Presumably, many consumers choose to report their quantity of use in hits rather than grams because they struggle to accurately report small numbers of grams. Moreover, the findings generally tend to be more extreme at the third quantile as compared to the median and findings at the first quantile tend to be less extreme, making it more difficult to detect differences. We believe this is a result of differences being amplified or diminished with more or less use (i.e., there is less of a difference between one and two hits as compared to 10 and 20 hits).

The findings for estimating mgTHC for concentrates indicate more exploration is needed. The median GPHR derived for all three MQHS groups was larger than the SHS GPHR comparison value, which was determined using estimates from prior laboratory studies. The large hit size group's GPHR was greater than the small and the medium hit size groups at the median, which did not differ from each other. However, the large hit size group's GPHR did not differ at the first or third quantile from the medium hit size group. All three MQHS groups produced greater estimates of mgTHC than the SHS approach. Generally, consumers struggle to report small numbers of grams of concentrate accurately (Prince et al., 2018). The response options in our survey for the number of grams consumed per day likely did not include a low enough quantity category, as the lowest was 1/16g, causing a potential floor effect and overestimating mgTHC. This likely artificially increased estimates for low-end obfuscated potential differences in GPHRs and associated mgTHC estimates between those who reported small and medium hit sizes.

Several additional methodological limitations should be noted. The study sampling methodology was not designed to be representative of all cannabis consumers. Thus, the majority of the analytic sample were Non-Hispanic White

individuals who reported frequent and heavy cannabis use. All respondents self-selected to participate via an advertisement on Facebook or Instagram. Self-report and recall biases may also influence the findings.

Conclusions and Future Studies

This study demonstrated a novel approach (MQHS GPHR) to account for varying hit sizes when using detailed cannabis use survey items to estimate mgTHC from smoked or vaped cannabis products. The MQHS approach performed well for estimating consumption from flower products, but more work is needed to test its value for concentrate products. We believe these data represent an important first step in demonstrating how new standard GPHRs can be developed for an MQHS approach, such that future studies only need to ask about qualitative hit size to assign an individual a GPHR. Specifically, subsequent studies need to include more expansive response options on the lower end of consumption to avoid GPHR floor effects. Moreover, the GPHRs derived in this study for the three MQHS groups for flower products should not be used as new standard GPHR estimates until these findings are replicated in studies with larger and more representative samples. Additionally, future laboratory studies should evaluate how accurately consumers can estimate the number of hits to finish a half-gram of cannabis product using their preferred method. This would likely involve the participant estimating the number of hits to finish a half gram prior to consuming any cannabis and the researcher observing a participant consume a half gram and counting the number of hits they consume. Such future studies would help validate the methods needed to derive the multiple qualitative hit size GPHRs. Future studies that incorporate objective measures of consumption (e.g., topography, urinalysis) could aide in validating the MQHS. Further, studies can assess for other cannabinoid use and explore moderators (e.g., biological sex differences) that may influence mgTHC exposure and dosing effects. Lastly, future studies can assess the clarity of the items used in this study.

We hope that this limited demonstration stimulates others to investigate similar approaches to capturing variability in hit size to develop standard GPHRs for this type of multiple qualitative hit size approach. Efforts to improve cannabis estimation models are sorely needed, and accounting for individual variation in hit size will improve estimates of mgTHC and facilitate more accurate studies of the effects of cannabis consumption.

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