

# Evaluating surveillance definitions of HIV viral suppression 2015–2019: Which definition best detected barriers to care?

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## Abstract

**Background:** People living with HIV (PLWH) who have not achieved or maintained viral suppression post-diagnosis likely face multiple barriers to HIV care. To identify these barriers a universally accepted definition of viral suppression is needed. The most common definition, the Center for Disease Control and Prevention (CDC) definition, contains simplifying assumptions that may misclassify individuals and attenuate associations. In this study, we evaluated alternative definitions of viral suppression on their ability to identify barriers to care.

**Design and methods:** We used HIV surveillance data to classify participants of the 2015–2019 Washington Medical Monitoring Project (MMP) as virally suppressed or not using the CDC definition and two definitions that assess viral suppression over a longer period (“Enriched” and “Durable”). We identified barriers to suppression from literature (unstable housing, illicit drug use, poor mental health, heavy drinking, recent incarceration, racism, and poverty) and measured them using interview questions from MMP. We compared the rate ratios (RR) of being not virally suppressed using each definition for each barrier.

**Results:** There were 858 PLWH in our study. All viral suppression definitions classified a similar proportion of people as suppressed (85%–89%). The durable viral suppression definition consistently yielded the largest rate ratios (e.g. unstable housing: CDC RR = 1.3, 95% CI 0.9–1.8; Enriched 1.5, 95% CI 1.0–2.2; Durable 2.2, 95% CI 1.6–3.1) and reclassified 10% of the population relative to the CDC definition.

**Conclusions:** Longitudinal definitions for viral suppression may yield less misclassification and serve as superior tools for identifying and curtailing barriers to HIV care.

## Keywords

HIV, viral suppression, HIV surveillance, barriers to care

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## Background

Lab-based human immunodeficiency virus (HIV) surveillance is a core tool for assessing barriers to HIV care at a population level in the United States.<sup>1</sup> One of most common methodologies for assessing successful HIV treatment using HIV surveillance data is the Centers for Disease Control and Prevention (CDC) viral suppression definition.<sup>2</sup> The CDC definition is simple and can be applied to contemporary data, but it has strong missing data assumptions and may misclassify people living with HIV (PLWH) as unsuppressed if they do not receive annual viral load testing or if viral load testing is not consistently reported to

surveillance systems. There are alternative ways of measuring viral suppression, but it is unclear how they compare in their ability to detect barriers to HIV care.<sup>1</sup>

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The CDC viral suppression definition is a point-in-time measure that categorizes a person as virally suppressed if their most recent viral load test in the past 12 months had a result of  $<200$  copies/mL. If a person had no viral load test reported in the past 12 months, then they are classified as not virally suppressed.<sup>2</sup> The second statement relies on two assumptions which are necessary for correct classification: (1) Yearly viral load testing is a prerequisite to obtaining antiretroviral therapy and (2) The surveillance system has complete capture of viral load testing. If either of these assumptions are violated, the definition would misclassify some individuals who are virally suppressed. The first assumption can be violated during a disruption to normal medical operations, such as during the 2020–2022 coronavirus disease (COVID-19) pandemic.<sup>3</sup> During this time period, many physicians moved to remote visits and forwent regular viral load testing to reduce the spread of COVID-19. The second assumption is violated on a routine basis when individuals receive viral load testing that isn't reported, such as when they receive care in a state other than the one where they live; live in states with incomplete reporting laws; or receive care in federal facilities that don't recognize state reporting laws.

Although these assumptions may be necessary when analyzing current data, retrospective analyses may benefit from considering additional viral load test results that occur after the time point of interest. For example, the viral suppression status of a person who has not received viral load testing in 12 months may appear to be different depending on whether their next viral load result is undetectable or viremic. Several studies have identified the benefits of considering viral load longitudinally, but not in the context of barriers to HIV care.<sup>4,5</sup> More accurate ascertainment of point in time viral load status would decrease misclassification bias and improve identification of barriers to HIV care. If the CDC definition has non-differential misclassification with respect to the exposure, then we would expect to see larger effect sizes with improved viral suppression definitions on average. If the CDC definition has differential classification, then the relationship would be more complex.<sup>6</sup>

There have been some efforts to develop and compare alternative definitions for viral suppression, but none have evaluated their ability in the context of detecting barriers to care. Crepaz et al. evaluated the CDC's definition in terms of transmission probability and found it to be an inconsistent measure of stable viral suppression.<sup>7</sup> They used a "durable viral suppression" metric as one of their gold standards, defined as having all viral loads  $<200$  copies/mL during the 2-year study period. There are several studies attempting to integrate the entirety of a person's viral load history into a longitudinal model, but it is unclear if these are feasible to implement these in a routine setting.<sup>4,5</sup>

The purpose of this analysis was to evaluate two candidate viral suppression definitions that incorporate

subsequent viral load information into classifying viral suppression and relax the assumptions of the CDC viral load definition. We will describe the populations characterized differently by each definition, compare the effect sizes from models relating each definition to known barriers to HIV care, and characterize the misclassification mechanism of the CDC definition relative to the two alternatives. By identifying more sensitive tools for detecting barriers to HIV care, we offer the ability to improve HIV care delivery.

## Design and methods

### Study design and setting

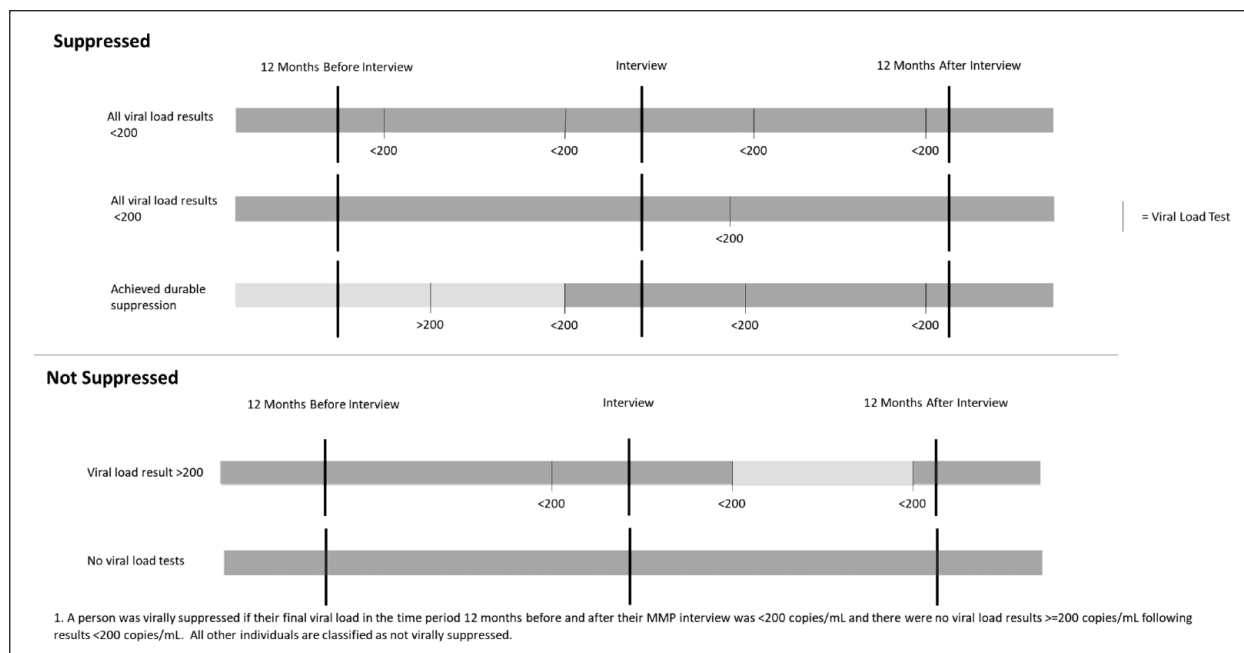
This was a retrospective cross-sectional study of participants of the Medical Monitoring Project (MMP) in Washington State in the five cycle years 2015 and 2019. Cycle years start in June of the given year and go through May of the following year. MMP is a surveillance system that captures detailed information on behavioral and clinical characteristics of a sample of people living with HIV in the United States via structured interviews and medical record abstractions.<sup>8</sup> Sampling is a multi-stage process performed centrally by the Centers for Diseases Control and Prevention from a surveillance roster of people living with HIV in Washington at the beginning of the project cycle.<sup>9</sup> The data is collected by health department staff, who are assigned a random sample of PLWH to contact primarily via letter and phone call. The data is accompanied by weights to correct for non-response bias. Individuals were included in the study if they participated in the MMP while living in Washington State. No power calculations were performed as this was a secondary analysis of existing data.

The data source for viral load test results for this analysis was the Washington State HIV surveillance system. The Washington State HIV surveillance system is a longitudinal database of PLWH including laboratory results collected during the course of routine HIV care and reported to the state by law.<sup>10</sup> Viral load data is submitted via electronic laboratory reporting and supplemented with active collection of additional information about new HIV diagnoses, changes of residence, death, and demographics.

### Variable definitions

We used viral load test results data from the surveillance system to ascertain viral suppression status three ways:

- (1) CDC Viral Suppression Definition: A person was virally suppressed if they have received a viral load test in the 12 months prior to their MMP interview and their most recent viral load test result was  $<200$  copies/mL. Individuals with a viral load



**Figure 1.** Examples of durable viral suppression definition for identifying barriers to HIV care.<sup>1</sup>

result of  $\geq 200$  copies/mL and individuals who did not have a viral load test in the 12 months prior to their MMP interview were classified as not virally suppressed.<sup>2</sup>

- (2) **Enriched Viral Suppression Definition:** Same as CDC Viral Suppression Definition except for those who did not have a viral load test in the 12 months prior to their MMP interview. For these individuals, the first viral load test *after* their interview was used to determine viral suppression status with a cutoff of 200 copies/mL. The subsequent viral load test need not occur within 12 months of the interview. Those with no subsequent viral load test were classified as not virally suppressed.
- (3) **Durable Viral Suppression Definition:** A person was virally suppressed if their final viral load test result in the time period 12 months before and after their MMP interview was  $< 200$  copies/mL and there were no viral load results  $\geq 200$  copies/mL following any results  $< 200$  copies/mL in this 24-month window. All other individuals are classified as not virally suppressed. This is a modification of the viral suppression definition from Crepaz et al.<sup>7</sup>

The durable viral suppression definition is illustrated in Figure 1. Briefly, it represents individuals who sustained or achieved Crepaz et al.'s durable viral suppression definition in the 12 months before and after their MMP interview (viral load values consistently  $< 200$  copies/mL). The two additional viral suppression definitions were selected

a priori without reference to population values or associations with barriers to care.

In consultation with MMP staff, we identified a list of barriers to care that were measured in the MMP questionnaire, have a perceived strong influence on a person's ability to access HIV care and maintain ART adherence, and were common among PLWH in Washington state. The barriers we identified were unstable housing,<sup>11</sup> illicit drug use,<sup>12</sup> poor mental health,<sup>13</sup> heavy drinking,<sup>14</sup> recent incarceration,<sup>11</sup> racism,<sup>15</sup> and poverty.<sup>16</sup> All were measured via self-report in the MMP interview. Unstable housing reflected whether a participant reported living on the street, shelter, or car; needing housing, rent, or utility assistance; or living with friends due to financial problems in the past 12 months. Illicit drug use reflected whether a person reported using meth, heroin, cocaine, or non-prescription opiates in the past 12 months. Poor mental health reflected having 13 or more days of poor mental health in the past 30 days.<sup>17</sup> Heavy drinking was defined using the CDC criterion of "heavy drinking" in the past 30 days, which is an average of more than two alcoholic drinks per day for men, more than 1 alcoholic drink per day for women or "binge drinking," which is 5 or more alcohol drinks in one sitting for men, 4 or more alcohol drinks in one sitting for women. Recent incarceration was defined as spending 1 or more night in prison or jail in the past 12 months. Racism was a comparison of the groups with the lowest population viral suppression in Washington (Black, American Indian/Alaska Native, Native Hawaiian, and Pacific Islander) to all others. Poverty was a comparison of those with a household income below 139% of the Federal Poverty Level to all others.

## Analysis

We performed univariate analyses to describe our study population across the dimensions of gender (male, female, transgender male or female or other gender identity); sexual behavior (any male-male sexual contact [MSM] vs no MSM per the gender of a person's partners in past 12 months or self-report if no partners in past 12 months); age (18-24, 25-34, 35-44, 55+); race (American Indian/Alaskan Native, Asian, Black, Hispanic/Latina/o/x, Multiracial, Native Hawaiian or Pacific Islander, White); income (<139% Federal Poverty Level, 139%-400% Federal Poverty Level, >400% Federal Poverty Level); insurance status (Private, Public, Uninsured), and time since diagnosis (<5 years, 5-9 years, 10+ years). We estimated the proportion of the population that differed between the alternative viral suppression definitions and the CDC definition and stratified this by the reason for the difference.

Next, we compared the rate ratios that resulted from each viral suppression definition using log binomial models. We modeled the probability of being not virally suppressed for each barrier to care. We calculated risk ratios and their 95% confidence intervals from crude single-variable models and multi-variable models adjusted for sex/sexual behavior (MSM, non-MSM male, female), race, age, and income. Race and income were not included as adjustment variables in models of racism and poverty, respectively.

Finally, to investigate the mechanism for the differences in rate ratios, we described the sensitivity and specificity of the CDC definition relative to the alternative definitions for each level of the barriers to care. In this context, the sensitivity was defined as the probability that a person was classified as virally suppressed using the CDC definition given they were classified as virally suppressed by the alternative definition. Specificity was the probability that a person was classified as not virally suppressed using the CDC definition given they were classified as not virally suppressed by the alternative definition.

We stratified sensitivity and specificity calculations by the different levels of the barriers to care (exposures) in order to classify the differences between the viral suppression definitions as differential or non-differential misclassification. If the sensitivities or specificities were different across a given exposure, then the misclassification was considered differential; if the sensitivities and specificities were the same across a given exposure, then the misclassification was considered non-differential.<sup>18</sup> We tested for differences across the barriers to care using Fisher's exact test and an alpha of 0.05 (bivariate analysis).

All analysis were performed with weights to account for non-response to the MMP survey. All analyses met the criteria for program evaluation and were exempt from IRB review. Data was collected as surveillance activities as mandated by Washington state law. All analyses were performed in SAS version 9.4.<sup>19</sup>

**Table 1.** Demographics of participants of the medical monitoring project, Washington State 2015-2019.<sup>a</sup>

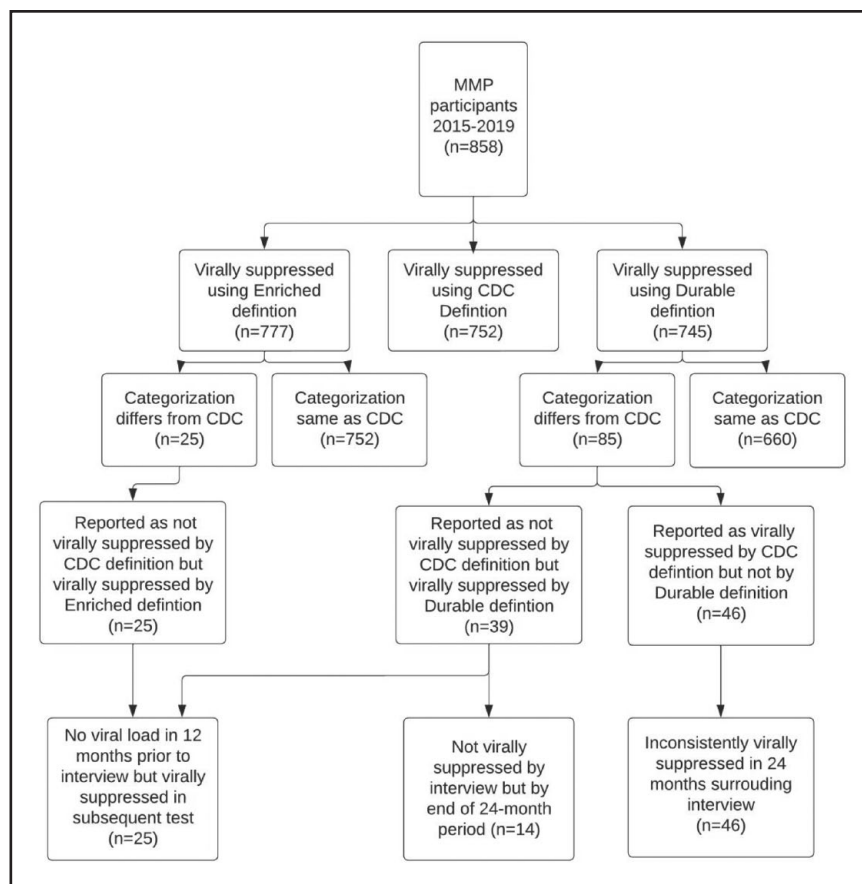
Variable	Value	N, Weighted %
Gender	Male	739 (84)
	Female	112 (15)
	Transgender Male or Female or Other Gender Identity	7 (1)
Sexual activity <sup>b</sup>	Any Male-Male Sexual Contact	617 (70)
	No Male-Male Sexual Contact	201 (30)
Age	18-24	10 (1)
	25-34	94 (10)
	35-44	176 (21)
	45-54	284 (34)
	≥55	294 (34)
Race	American Indian/Alaska Native	9 (1)
	Asian	22 (2)
	Black	123 (15)
	Hispanic or Latina/o/x	122 (14)
	Multiracial	82 (9)
	Native Hawaiian or Pacific Islander	4 (1)
	White	496 (57)
Income	<139% Federal Poverty Level	341 (43)
	139-400% Federal Poverty Level	312 (37)
	>400%+ Federal Poverty Level	176 (21)
Insurance	Private	375 (43)
	Public	468 (56)
	Uninsured	4 (1)
Time since diagnoses	<5 years	118 (13)
	5-9 years	165 (20)
	≥10 years	575 (67)

<sup>a</sup>Data collected from interview of a random sample of people living with HIV in Washington State. Percentages weighted to account for non-response rates.

<sup>b</sup>Sexual activity ascertained by the gender of sexual partners in the past 12 months or by stated preference if no partners in the last 12 months.

## Results

Data from 858 MMP participants were included in this analysis. The majority were male (84%), MSM (70%), and over the age of 44 years (68%). Fifty-seven percent identified as White, 15% as Black, 14% as Hispanic or Latina/o/x, and 14% as another race. Forty-three percent of the study population had a household income less than 139% of the federal poverty level and 56% relied on public insurance for their medical care. Full demographics can be found in Table 1.



**Figure 2.** Differences between Durable, Enriched, and CDC Viral Suppression Definitions Among Participants of the Washington State Medical Monitoring Project, 2015–2019.

Of the 858 participants, 55 (6%) had no viral load results reported in the year before and after their MMP interview. The remainder contributed 3459 viral load results during this time period, of which 3200 (93%) were <200 copies/mL.

### Comparison of viral suppression definitions

Of the 858 members of the study population, 752 (85%) were virally suppressed according to the CDC viral suppression definition, 777 (89%) were virally suppressed according to the enriched viral suppression definition, and 745 (85%) were virally suppressed according to the durable viral suppression definition.

There were 25 individuals who were classified differently by the CDC and enriched viral suppression definitions, representing 3% of the study population. One hundred percent of these individuals were PLWH who did not have a viral load reported in the 12 months prior to the interview, but whose subsequent viral load was <200 copies/mL (Figure 2).

There were 85 individuals who were classified differently by the CDC and durable viral suppression

definitions, representing 10% of the population. Of the 85, 39 (46%) were classified as not virally suppressed by the CDC definition and virally suppressed by the durable definition. Twenty-five of these were individuals who had no viral load in the 12 months prior to the interview, but whose subsequent viral loads were all <200 copies/mL. This is the same population that was categorized discordantly by the CDC and enriched definitions. The other 14 achieved sustained viral suppression during the 24-month period of the durable definition but had not done so by the time of the interview. The remaining 46 (54%) were classified as virally suppressed by the CDC definition and not virally suppressed by the durable definition; these were individuals whose final viral load before their interview was <200 copies/mL, but who had a viral load  $\geq$ 200 copies/mL within a year of their interview.

### Relationship with barriers to care

Two-hundred and seventy-two (32%) of the study population were classified as unstably housed, 167 (19%) as using illicit drugs, 174 (20%) as having poor mental health, 139 (16%) as engaging in heavy drinking, and 34 (3%)

**Table 2.** Risk ratio of viremia across multiple barriers to HIV care using different definitions of viral suppression, Washington State 2015–2019.<sup>a</sup>

Model <sup>b</sup>	Variable	CDC Definition (95% CI)	Enriched Definition (95% CI)	Durable Definition (95% CI)
Crude	Unstable Housing	1.4 (1.0–2.0)	1.7 (1.2–2.5)	2.4 (1.7–3.2)
	Poor Mental Health	0.9 (0.6–1.4)	0.9 (0.6–1.5)	1.4 (1.0–2.0)
	Illicit Drug Use	2.0 (1.5–2.8)	2.6 (1.8–3.8)	3.6 (2.7–4.9)
	Heavy Drinking	0.7 (0.4–1.1)	0.8 (0.4–1.4)	0.8 (0.5–1.3)
	Poverty	1.3 (1.0–1.9)	1.5 (1.0–2.2)	1.7 (1.2–2.4)
	Racism (Black, AI/AN, NHOPI)	1.4 (0.9–2.0)	1.6 (1.0–2.4)	1.6 (1.1–2.3)
	Recent Incarceration	0.9 (0.35–2.4)	1.2 (0.5–3.2)	2.1 (1.2–3.7)
Adjusted	Unstable Housing	1.3 (0.9–1.8)	1.5 (1.0–2.2)	2.2 (1.6–3.1)
	Poor Mental Health	0.9 (0.6–1.3)	0.9 (0.5–1.4)	1.4 (1.0–2.0)
	Illicit Drug Use	1.9 (1.4–2.7)	2.6 (1.8–3.8)	3.4 (2.5–4.6)
	Heavy Drinking	0.7 (0.4–1.1)	0.7 (0.4–1.3)	0.7 (0.5–1.2)
	Poverty	1.3 (0.9–1.8)	1.4 (0.9–2.1)	1.8 (1.3–2.5)
	Racism (Black, AI/AN, NHOPI)	1.2 (0.8–1.8)	1.4 (0.9–2.3)	1.7 (1.1–2.4)
	Recent Incarceration	0.9 (0.4–2.1)	1.2 (0.5–2.9)	1.8 (1.1–3.1)

AI/AN: American Indian or Alaska Native; NHOPI: Native Hawaiian or Pacific Islander.

<sup>a</sup>Viral load status was ascertained using laboratory data obtained through mandatory reporting. CDC Definition: a person is virally suppressed if they received a viral load in the 12 months before their MMP interview and the result of their viral load preceding the interview was <200 copies per mL; Enriched Definition: same as CDC definition, except for those without a viral load in the 12 months before their interview. These individuals were classified based on the result of their first viral load after their interview (<200 or ≥200 copies/mL); Durable Definition: a person is virally suppressed if the result of their final viral load in 12 months before and after their interview was <200 copies/mL and there were no viral load results ≥200 copies/mL following results <200 copies/mL.

<sup>b</sup>All models weighted to adjust for survey non-response. Adjusted estimates from log binomial model adjusted for gender, race, and age.

having been incarcerated in the past 12 months. One-hundred and thirty-six (17%) identified as single-race Black, American Indian/Alaska Native, Native Hawaiian, or Pacific Islander, and 342 (43%) had a household income under 139% of the federal poverty level.

The risk ratios of being not virally suppressed using the durable and enriched definitions were consistently higher or equal to that of the CDC definition (Table 2), suggesting that they were better able to detect barriers to care than the CDC definition. The durable definition yielded the largest risk ratios, suggesting it has the highest power for detecting barriers to care. This was true for both the crude and adjusted (aRR) models. The largest aRRs corresponded to unstable housing (CDC Definition: 1.3, 95% CI 0.9–1.8; Enriched Definition 1.5, 95% CI 1.0–2.2; Durable Definition: 2.2, 95% CI 1.6–3.1) and illicit drug use (CDC Definition: 1.9, 95% CI 1.4–2.7; Enriched Definition 2.6, 95% CI 1.8–3.8; Durable Definition: 3.4, 95% CI 2.5–4.6). All three definitions found heavy drinking to be positively associated with being virally suppressed (CDC Definition: 0.7, 95% CI 0.4–1.1; Enriched Definition 0.7, 95% CI 0.4–1.3; Durable Definition: 0.7, 95% CI 0.5–1.2), although none of the three aRR were statistically significant.

### Mechanism of misclassification

Using the enriched definition as true positive, the CDC definition exhibited high sensitivity (96%–98%) and 100%

specificity, regardless of exposure to the known barriers to care (Table 3). There was no evidence for differential misclassification with respect to any of the barriers of care (all  $p > 0.05$ ).

Relative to the durable definition, the CDC definition exhibited high sensitivity (93%–100%) and low specificity (48%–71%). There was a significant difference in specificity across the variable poor mental health (48% for exposed, 69% for unexposed,  $p = 0.05$ ). Although they did not reach the threshold for significance, there were large differences in the specificity across exposure status for the other barriers to care.

### Discussion

In this study we found that the two alternative viral suppression definitions reclassified a small proportion of the study population relative to the CDC definition (enriched 3%, durable 10%) but yielded an increased ability to identify barriers to care. We interpret this reclassification as improved ascertainment of viral suppression status that represents better tools for identifying barriers to HIV care.

The risk ratios of viral suppression were farther from the null for 5 out of 7 barriers to care when using the enriched viral suppression definition as compared to the CDC definition. We did not find evidence that relationships between the enriched criteria and the CDC definitions were dependent on the barriers to care that we

**Table 3.** Sensitivity and specificity of CDC viral suppression definition relative to alternative definitions by barriers to HIV care, Washington State 2015–2019.<sup>a,b</sup>

Comparison	Variable	Sensitivity exposed <sup>c</sup>	Sensitivity unexposed	p-Value	Specificity exposed	Specificity Unexposed	p-value
CDC vs Enriched	Unstable Housing	96% (94–99%)	96% (94–98%)	0.80	100% (NE-NE)	100% (NE-NE)	-
	Poor Mental Health	96% (92–100%)	96% (94–98%)	0.93	100% (NE-NE)	100% (NE-NE)	-
	Heavy Drinking	98% (96–100%)	96% (94–97%)	0.14	100% (NE-NE)	100% (NE-NE)	-
	Illicit drug Use	97% (94–100%)	96% (94–98%)	0.64	100% (NE-NE)	100% (NE-NE)	-
	Racism (Black, AI/AN, NHOPI)	97% (93–100%)	96% (94–98%)	0.79	100% (NE-NE)	100% (NE-NE)	-
	Poverty	96% (94–99%)	96% (94–98%)	0.98	100% (NE-NE)	100% (NE-NE)	-
	Recent Incarceration	100% (NE-NE)	96% (94–98%)	NE	100% (NE-NE)	100% (NE-NE)	-
CDC vs Durable	Unstable Housing	94% (92–96%)	94% (90–98%)	0.99	56% (43–70%)	71% (58–83%)	0.11
	Poor Mental Health	94% (92–96%)	94% (90–99%)	0.83	48% (29–67%)	69% (58–79%)	0.05
	Heavy Drinking	93% (91–96%)	97% (93–100%)	0.22	59% (35–83%)	64% (54–74%)	0.71
	Illicit drug Use	94% (92–96%)	92% (87–98%)	0.47	55% (41–69%)	70% (58–82%)	0.11
	Racism (Black, AI/AN, NHOPI)	94% (92–96%)	94% (89–99%)	0.87	65% (47–84%)	62% (52–73%)	0.79
	Poverty	94% (92–97%)	93% (90–97%)	0.58	57% (44–70%)	66% (53–80%)	0.33
	Recent Incarceration	100% (NE-NE)	94% (92–96%)	NE	43% (11–76%)	65% (55–74%)	0.20

AI/AN: American Indian or Alaska Native; NHOPI: Native Hawaiian or Pacific Islander.

<sup>a</sup>Viral load status was ascertained using laboratory data obtained through mandatory reporting. CDC Definition: a person is virally suppressed if they received a viral load in the 12 months before their MMP interview and the result of their viral load preceding the interview was <200 copies per mL; Enriched Definition: same as CDC definition, except for those without a viral load in the 12 months before their interview. These individuals were classified based on the result of their first viral load result after their interview (<200 or ≥200 copies/mL); Durable Definition: a person is virally suppressed if the result of their final viral load in 12 months before and after their interview was <200 copies/mL and there were no viral load results ≥200 copies/mL following results <200 copies/mL.

<sup>b</sup>Sensitivity is the probability that a person was classified as virally suppressed using the CDC definition given they were classified as virally suppressed by the alternative definition. Specificity was the probability that a person was classified as not virally suppressed using the CDC definition given they were classified as not virally suppressed by the alternative definition.

<sup>c</sup>Percentages calculated using weights to account for survey non-response.

examined. Taken together, this suggests that the differences between the definitions come from non-differential misclassification of viral suppression by the CDC definition. This is consistent with our framework that the limitations of the CDC definition are the product of large, structural inefficiencies (such as laboratory reporting laws) and not individual characteristics or barriers to care.<sup>20</sup> This would place the rate ratios from the enriched criteria as a more accurate measure of the same underlying construct as the CDC criteria.

For the durable viral suppression definition, the risk ratios of viral suppression were farther from the null for 6 out of 7 barriers to care relative to the CDC definition. Unlike the enriched definition, we saw some evidence of differential misclassification of viral suppression across barriers to care, albeit it was not clear how much of this was driven by chance. The differences in specificity across barriers to care stem from the categorization of people who are unstably suppressed, which is not reliably captured by the point-in-time CDC definition. It is reasonable to expect that that people with larger barriers to care would more likely be unstably suppressed, but our findings demonstrate that the durable definition is not necessarily measuring the same construct as the CDC definition.

Although to the authors' knowledge this study is the first to examine this topic, our results are broadly

consistent with the work of Crepaz et al, who found that the CDC definition was not a consistent measure of HIV transmission risk. Although there have not been many studies examining the relationship between the definition of viral suppression and barriers to care, several other studies have identified the benefits of considering viral load longitudinally.<sup>4,5</sup> From a theoretical perspective, a large attenuation of the rate ratios is consistent with a measure with less than perfect specificity.<sup>6</sup>

Our study has several strengths. We were able to examine a wide range of barriers to care, which gives us confidence that the larger risk ratios are the product of an improved measurement of an actual effect and not underlying confounding relationship. The latter would require a strong confounding across multiple domains, and it is not clear what this would be. This is further bolstered by our ability to describe the discordance between the definitions; in each case, the difference reflected intentional changes to the classification scheme. Namely:

- (1) The enriched and durable definitions both reclassified a person who did not have a viral load test in the 12 months prior to their interview as “suppressed” if viral loads after their interview had a result of <200 copies/mL. This allows for

an individual to be correctly classified if they maintained viral suppression during a period where their labs were not consistently performed or reported.

- (2) The durable definition subsequently reclassified people who had results that were inconsistently  $<200$  copies/mL as not virally suppressed. For detection of people who are struggling to engage in care, this may be a more accurate classification than the other definitions, which only represent a person's status at an arbitrary point in time as much as a year before the interview.
- (3) Finally, the durable definition considers someone who achieves consistent viral suppression during the 2 year interval as suppressed, regardless of whether they began the interval with a viral load  $\geq 200$  copies/mL. This is a step away from a true biological definition of viral suppression but may be an improvement for classifying people who are successfully engaging in care.

There are several weaknesses to our evaluation that should be acknowledged. First, our analysis of differential misclassification relied upon a small number of individuals who were classified differently and was potentially underpowered; it is possible that there was more differential classification than we were able to detect. Secondly, our measurements of barriers to viral suppression are imperfect and they rely upon imprecise categorizations, self-report, and a potentially non-representative sample. We posit this as an explanation for the unexpected association between heavy drinking and viral suppression. This is not consistent with findings from other studies.<sup>14,21</sup> It is also likely that there was under ascertainment of American Indian/Alaska Native individuals.<sup>22</sup> Finally, the MMP data used in this project represents only the subset of PLWH who are reachable by recruitment and interested in and willing to participate. This may disproportionately exclude individuals with high barriers to HIV and yield low prevalence estimates for the barriers to care that we examined. It is not clear that this would affect the comparative performance of the viral suppression definitions, however.

Although the candidate viral definitions have some improved measurement properties, they may also have characteristics that make them less desirable for surveillance use. As the enriched and durable definitions use data collected after the time point of interest, they may change over time as new data is added to a surveillance system. However, this is not a unique phenomenon, as any definition can be affected by delays in laboratory reporting or interstate deduplication. The viral suppression definitions are also not suitable for analyzing current data, as they require at least a year to ascertain viral suppression status. This would limit their utility for program monitoring.

Finally, some barriers to care, such as illicit drug use were significant regardless of the definition used; in this case using a definition that is consistent with other surveillance data products may be preferable.

In our analysis we demonstrated the potential of two alternative viral suppression definitions to better detect – and then lessen – barriers to HIV care in the United States. The alternative definitions are relatively simple to calculate and do not require additional data sources. We suggest that researchers seeking to retrospectively identify barriers to HIV care use our enriched or durable viral suppression definitions depending on their goals, as these definitions better detect barriers to care. Doing so will bolster their ability to identify obstacles to HIV care and improve HIV healthcare delivery systems nationwide.

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### Public health significance

Population-level viral suppression is among the most common ways to identify barriers to human immunodeficiency virus (HIV) care and monitor HIV programs. However, there has been insufficient attention paid to how viral suppression should be defined and what parameterization offers the best ability detect barriers to care.

In our study, we found that the most common viral suppression definition used by HIV surveillance programs and the Center for Disease Control and Prevention (CDC) was not able to detect barriers to care as well as other definitions found in the literature. The best definition we identified reclassified 10% of our study population relative to the CDC definition and would increase researchers' ability to detect obstacles to successful HIV treatment.

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