Diversity in Digital Pill Systems: Differences in Perceptions and Attitudes Towards Use of a Digital Pill System for HIV Pre-Exposure Prophylaxis Among Men Who Have Sex with Men with Diverse Racial and Ethnic Identities

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Abstract

Nonadherence, particularly among men who have sex with men (MSM) with substance use disorders, increases the risk of HIV acquisition. Measuring adherence to HIV pre-exposure chemoprophylaxis (PrEP), and responding to suboptimal adherence or changes in adherence behavior remains a challenging public health problem. Despite the importance of accurate adherence measurement, there is no gold standard for detecting medication ingestion events in HIV research. Current adherence measures indirectly infer ingestion events or measure medication concentrations over time, yet such approaches fail to provide direct confirmation of ingestions and contextual information surrounding adherence and nonadherence. A digital pill system (DPS) – a novel tool that leverages ingestible radiofrequency sensors to measure actual ingestion events – may advance adherence measurement in HIV research. We examined and compared the willingness of MSM across racial and ethnic identities to operate a DPS in the context of PrEP adherence measurement and suggest potential future applications of this technology.

Keywords: Digital pill systems, ingestible sensors, HIV pre-exposure prophylaxis, medication adherence

1. Introduction

HIV remains one of the greatest public health epidemics worldwide. In 2019, there were an estimated 36,801 HIV diagnoses across the United States (U.S.), most of which were acquired via exposure during sexual intercourse and/or injection drug use (Centers for Disease Control and Prevention, 2021a, 2021b). Men who have sex with men (MSM) accounted for approximately 69% of these HIV diagnoses in the U.S.

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and dependent areas in 2019 (Centers for Disease Control and Prevention, 2021a, 2021b).

Among MSM in the U.S., two separate trajectories of the HIV epidemic exist. In 2019, Black/African American MSM (25% of incident cases) and Hispanic/Latinx MSM (21%) accounted for nearly half of all incident HIV cases in the U.S. and dependent areas (Centers for Disease Control and Prevention, 2021a). Current strategies to end the HIV epidemic seek to reach the 90-90-90 UNAIDS goals Joint UNAIDS, 2014) by increasing access to HIV testing and ART, as well as through HIV prevention efforts via oral pre-exposure chemoprophylaxis (PrEP). Several pivotal clinical trials and demonstration projects have additionally established the efficacy of PrEP for preventing HIV infection. Despite its promise, however, the effectiveness of PrEP is closely tied to an individual's degree of adherence. Clinical trials and epidemiological studies continue to demonstrate that, of all PrEP-eligible individuals, MSM – and especially those with substance use disorder (SUD) – are most at risk for PrEP nonadherence and subsequent HIV acquisition.

Given the importance of PrEP adherence for optimizing HIV prevention efforts, multiple modalities have been developed and studied for measuring adherence. These strategies range from indirect measures of adherence, such as self-report – which merely implies medication ingestions and is subject to recall and social desirability biases – to direct adherence measures (Spinelli et al., 2020), including directly observed therapy (DOT) and pharmacological measures that can provide confirmation of drug levels in blood or urine – which are more costly and difficult to scale (Chai et al., 2015). While there is no gold standard for adherence measurement, direct measures are particularly attractive, as they provide incontrovertible proof of medication ingestion. Moreover, depending on the specific method of direct adherence measurement, opportunities may exist to deliver personalized adherence interventions in response to specific patterns of medication-taking behavior – and in some cases, intervene at the moment in which nonadherence occurs (Chai, Mohamed, Goodman, et al., 2022).

Digital pill systems (DPS) represent a novel tool for the direct measurement of adherence patterns. DPS are comprised of an ingestible radiofrequency emitter integrated into a standard gelatin capsule, which overencapsulates a medication (e.g., PrEP). When ingested, the radiofrequency emitter is activated by gastric chloride ions, transmitting ingestion time data to a wearable Reader device, which stores and forwards the ingestion information via low energy Bluetooth (BLE) to a smartphone application and cloud-based interface. This permits both users and research or care teams to visualize adherence patterns on-demand, and can be used to deliver adherence interventions in real-time based on detected adherence or nonadherence (Figure 1). DPS have been utilized in prior investigations to measure adherence to PrEP among MSM with substance use (Chai, Mohamed, Bustamante, et al., 2022). This research has demonstrated that the technology is acceptable among MSM, who were willing to interact with it and expressed an interest in receiving PrEP adherence feedback from the system (Chai, Goodman, Bronzi, et al., 2022). This work also established that key insights around adherence patterns can be extracted from DPS-detected data and associated with factors that mediate and influence PrEP nonadherence.

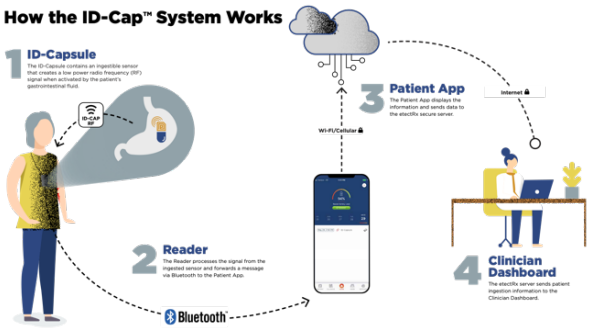

Figure 1. Digital pill system (DPS) operation
Image courtesy of etectRx (Gainesville, FL).

One way to conceptualize the use of DPS for adherence is as a behavior change support system (BCSS; Oinas-Kukkonen, 2013). Health BCSS leverage technical information systems to improve health outcomes via the use of behavior change models. Within the outcome/change matrix of BCSS research, DPS is well-suited to effect potential formation, alteration, and/or reinforcement of a behavior (Oinas-Kukkonen, 2013). In its current application, the behavior change being supported by the DPS is adherence to PrEP.

For any BCSS to be effective, acceptance of the technology is a crucial component. Although DPS have been used to measure adherence to a variety of pharmacotherapy regimens, including PrEP, acceptance of the technology has mostly been demonstrated through smaller pilot trials (Chai et al., 2022). Until DPS are deployed on a larger scale, especially in the context of HIV prevention, investigations that focus on DPS acceptability and examinations of factors that may be associated with acceptability and willingness to utilize such systems are especially important. In the present study, we report findings from a large, population-level quantitative assessment exploring factors that may influence willingness to utilize DPS for PrEP adherence measurement among MSM with substance use.

Prior research has generally shown high levels of acceptance of DPS and similar technologies (Chai, Goodman, Bronzi, et al., 2022). Notably, much of this

research has been conducted in samples with limited racial and ethnic diversity – despite the disproportionate burden of HIV in racial and ethnic minorities (Centers for Disease Control and Prevention, 2021a), and the importance of measuring adherence in racial and ethnic minorities. Medical mistrust, structural racism, and discrimination further contribute to disparities in PrEP uptake, adherence, and ultimately HIV protection. It is therefore important to examine racial and ethnic differences among MSM in attitudes toward adherence monitoring tools that support PrEP use.

This study sought to examine differences in attitudes toward DPS for PrEP adherence measurement among MSM by race and ethnicity. Owing to the extant literature on differences in medical mistrust among racial and ethnic minorities (Bazargan et al., 2021; Boulware et al., 2003), we hypothesized that there may be key differences in attitudes toward using DPS for PrEP between participants identifying as people of color (POC) and White participants. An improved understanding of potential barriers and facilitators of DPS uptake for PrEP adherence measurement among MSM of color will inform future research and clinical efforts to utilize DPS among diverse patient populations.

2. Materials and Methods

2.1. Recruitment

Through an advertising partnership with Grindr (West Hollywood, CA), a sexual networking site, we conducted an online quantitative assessment designed to understand the acceptance and perceptions of DPS among HIV-negative MSM in the U.S. with self-reported substance use. In January 2022, an inbox message containing a study advertisement and survey link was delivered to active Grindr users across the U.S., and was active for 24 hours. Interested individuals first completed an online screening survey to determine eligibility; if eligible and provided consent, enrolled participants then completed the survey via Qualtrics. The following validity checks were implemented in order to eliminate bots and verify that each participant was unique: CAPTCHA check for respondents, reported date of birth matched reported age, IP addresses were confirmed to be in the US, and the reported zip code matched their reported state.

2.2. Participants

Participants met the following inclusion criteria: (1) 18 years or older; (2) cisgender or transgender MSM; (3) self-reported HIV-negative; (4) currently on oral PrEP; (5) sexually active in the past three months; (6) score of two or higher on the CAGE Questions Adapted to Include Drug Use (CAGE-AID) indicating substance use (Health Resources & Services Administration, n.d.); and (7) current Grindr user.

2.3. Measures

The quantitative assessment was a one-time, online survey administered via Qualtrics. Questions covered sociodemographic information (e.g., age, sexual orientation, and race and ethnicity), sexual history (e.g., condom use in the past 3 months), substance use behavior (via the CAGE-AID), and views on bioethical principles related to DPS use (e.g., concerns regarding data privacy). Participants were presented with a video explaining the functions of DPS, and they were then asked about their perceptions of the technology, as well as their potential motivations for participating in future, theoretical DPS-based research studies to measure PrEP adherence. Additionally, participants completed a 6-item adapted version of the Group-Based Medical Mistrust Scale (GBMMS) to assess research and medical mistrust, and the 10-item System Usability Scale to assess perceptions of DPS usability (SUS; Knopf et al., 2021; U.S. General Services Administration, n.d.).

2.4. Analyses

Due to sample size limitations, in order to examine differences across race and ethnicity, we compared White, non-Hispanic individuals (referred to in this manuscript as White) with individuals indicating a racial identity that was not White and/or indicating a Hispanic ethnic identity (referred to in this manuscript as POC). As such, we created a dichotomous race/ethnicity variable of White or POC individuals. Subsequently, we utilized χ^2 tests of independence to examine associations between categorical variables and the dichotomous race/ethnicity variable. When examining associations between the dichotomous race/ethnicity variable and continuous variables, we utilized t-tests for two groups to assess for significant differences in means across the White and POC groups. Analyses were completed in R, version 4.2.0 (R Core Team, 2021).

3. Results

Participants were 157 adult, HIV-negative MSM who self-reported substance use, current use of oral PrEP, and sexual activity in the past three months. After dichotomization, 63.1% of the sample (n=99) identified as White and non-Hispanic, and 36.9% (n=58) as Hispanic and/or American Indian, Asian, Black, more than one race, or another racial category (POC; Table 1). With respect to racial identities among POC in the

present study, 7 (12.1%) participants identified as Black, 2 (3.4%) American Indian or Alaska Native, 6 (10.3%) as Asian, 4 (6.9%) as another race, and 19 (32.8%) participants identified as more than one race. With respect to ethnicity among POC, 34 (58.6%) participants identified as Hispanic or Latinx. There were no significant differences between White and POC groups on gender identity, sexual orientation, or income (*p*s > .05). However, there was a significant difference between POC and White participants on age (t (152.18) = 3.76, $p < 0.001$), such that POC (M=32.0, SD=8.3) were significantly younger than White participants (M=38.2, SD=12.4). Additionally, POC and White participants differed significantly in the frequency of condom use during sex over the past three months (χ^2 (4) = 15.72, p = 0.003), with 47.5% of White participants reporting never using a condom, compared to 25.9% of POC. A nearly even percentage of White and POC participants indicated sometimes (22.2% vs. 22.4%, respectively) or almost never (22.2% vs. 24.1%, respectively) using a condom during sex, and a greater proportion of POC participants indicated using a condom during sex almost every time (15.5%) or every time (12.1%), than did White participants (7.1% and 1.0%, respectively; Table 1).

Table 1. Sociodemographic characteristics (N=157)

	White (N=99, 63%) n (%)	POC (N=58, 37%) n (%)	χ^2 (df)
Gender identity			
Cisgender man	93 (93.9)	57 (98.3)	1.61 (1)
Trans-gender man	6 (6.1)	1 (1.7)	–
Sexual orientation			
Bisexual	19 (19.2)	10 (17.2)	0.37 (1)
Homo-sexual or "gay"	77 (77.8)	47 (81.0)	–
Other	3 (3.0)	1 (1.7)	–
Race			
American Indian or Alaska Native	0 (0%)	2 (3.4%)	-
Asian	0 (0%)	6 (10.3%)	-
Black	0 (0%)	7 (12.1%)	-
More than one race	0 (0%)	19 (32.8%)	-
Other	0 (0%)	4 (6.9%)	-
White	99 (100%)	20 (34.5%)	-
Hispanic / Latino			
No	99 (100%)	24 (41.4%)	-
Yes	0 (0%)	34 (58.6%)	-
Use of condoms during sex over past 3 months			
Never	47 (47.5)	15 (25.9)	15.72 (4)**
Almost never	22 (22.2)	14 (24.1)	–
Some-times	22 (22.2)	13 (22.4)	–
Almost every	7 (7.1)	9 (15.5)	–
Every time	1 (1.0)	7 (12.1)	–
	White (N=99, 63%) n (%)	**POC (N=58, 37%) n (%)**	***t* (df)**
Age			
Mean (SD)	38.2 (12.4)	32.0 (8.30)	3.76 (152.18)***
Median [Min, Max]	37.0 [18.0, 70.0]	31.0 [19.0, 64.0]	–

**p < .01; ***p < .001

With respect to potential motivations for participating in future DPS-based HIV prevention research, there were significant differences between White and POC participants on several variables (Table 2). Significant differences emerged between the two groups around the reported importance of access to free PrEP as a motivator for participation in DPS-based studies (χ^2 (4) = 10.15, p = 0.038). By percentage, more POC indicated that access to free PrEP would be a moderately (17.2%), very (22.4%), or extremely (43.1%) important motivator for future research participation, whereas more White participants (24.2%) indicated that access to free PrEP would be not at all important (5.2%). White and POC participants also differed significantly in their perceived importance of future research participation as an opportunity to talk about PrEP adherence with a study team (χ^2 (4) = 9.76, p = 0.045). A larger proportion of White participants (21.2%) indicated that this would only be a slightly important motivating factor for participation, whereas a greater proportion of POC indicated that this

opportunity would be a moderately (34.5%), very (25.9%), or extremely important (22.4%) motivator.

Table 2. Importance of motivations to participate in future DPS-based research (N=157)

	White (N=99) n (%)	POC (N=58) n (%)	χ^2 (df)
Access to free PrEP			
Not at all	24 (24.2)	3 (5.2)	10.15 (4)*
Slightly	12 (12.1)	7 (12.1)	–
Moderately	10 (10.1)	10 (17.2)	–
Very	17 (17.2)	13 (22.4)	–
Extremely	36 (36.4)	25 (43.1)	–
Opportunity to discuss adherence with study team			
Not at all	12 (12.1)	8 (13.8)	9.76 (4)*
Slightly	21 (21.2)	2 (3.4)	–
Moderately	31 (31.3)	20 (34.5)	–
Very	17 (17.2)	15 (25.9)	–
Extremely	18 (18.2)	13 (22.4)	–

Note. 5-point Likert-type scale indicates degree of importance ranging from "not at all" important to "extremely" important.
*p < .05

There were also significant differences between White and POC participants on willingness to share their DPS-recorded PrEP adherence information with others, including various study team members, individuals involved in their clinical care, as well as their sexual partners (Table 3).

White and POC participants differed on their reported willingness to share DPS-detected adherence data with a study principal investigator (χ^2 (4) = 16.74, p = 0.002), and with their primary care physician or PrEP prescriber (χ^2 (4) = 11.78, p = 0.018). With respect to sharing data with a study principal investigator, a greater proportion of White participants reported that they would be very (31.1%) or extremely (53.5%) willing, and a larger proportion of POC reported being moderately (19.0%), slightly (13.8%), or not at all (8.6%) willing. A greater proportion of White participants also indicated that they would be very (29.3%) or extremely (47.5%) willing to share adherence data with their primary care physician or PrEP prescriber, while a larger proportion of POC participants indicated being moderately (19.0%), slightly (17.2%), or not at all (6.9%) willing to do so. Additionally, White and POC participants differed significantly in terms of their willingness to share DPS-detected adherence data with casual sexual partner(s) (χ2 (4) = 12.78, p = 0.012). A greater percentage of POC indicated that they would be extremely willing (36.2%) to share PrEP adherence data with casual partners, whereas a larger percentage of White participants indicated that they would be only moderately (29.3%), or not at all (31.3%) willing.

A similar pattern of results emerged when examining participants' level of *concern* about sharing PrEP adherence data with others (Table 3). White and POC participants differed significantly in terms of concern around sharing PrEP adherence data with a study principal investigator (χ^2 (4) = 23.76, $p < 0.001$); nearly all White participants (86.9%) indicated they would be not at all concerned, as compared to just over half of POC participants (51.7%). By percentage, more POC (48.3%) than White (13.1%) participants indicated some level of concern about sharing data with a study principal investigator. There were similar differences in concern between White and POC participants regarding sharing data with an entire study team involved in a future research study (χ^2 (4) = 16.33, $p < 0.001$), with their primary care physician or PrEP prescriber (χ^2 (4) = 16.72, p = 0.002), and with all healthcare providers involved in their regular care (χ^2 (4) = 10.56, p = 0.036). A greater proportion of White participants were not at all (73.7%) or slightly (16.2%) concerned about sharing data with an entire study team, whereas a larger proportion of POC reported that they would be moderately (19.0%), very (3.4%), or extremely (13.8%) concerned (χ^2 (4) = 16.33, $p < 0.001$). A similar pattern of results emerged regarding concerns about sharing data with a primary care physician or PrEP prescriber, such that a larger percentage of White participants reported that they would be not at all concerned (72.7%), whereas a larger percentage of POC participants reported that they would be slightly (24.1%), moderately (8.6%), very (8.6%), or extremely (15.5%) concerned. Additionally, a larger proportion of White participants indicated that they would be not at all (53.5%) or slightly (25.3%) concerned about sharing data with all healthcare providers involved in their regular care, and a greater proportion of POC participants indicated that they would be moderately (15.5%), very (10.3%), or extremely (19.0%) concerned about doing so.

Table 3. Willingness and concerns around sharing PrEP adherence data with others (N=157)

	White (N=99) n (%)	POC (N=58) n (%)	χ^2 (df)
Willingness to share PrEP adherence data with…			
Lead study physician involved in the research			
Not at all willing	1 (1.0)	5 (8.6)	16.74 (4)**
Slightly willing	3 (3.0)	8 (13.8)	–
Moderately willing	11 (11.1)	11 (19.0)	–
Very willing	31 (31.3)	11 (19.0)	–
Extremely willing	53 (53.5)	23 (39.7)	–
Primary care physician or PrEP prescriber			
Not at all willing	4 (4.0)	4 (6.9)	11.78 (4)*
Slightly willing	3 (3.0)	10 (17.2)	–
Moderately willing	16 (16.2)	11 (19.0)	–
Very willing	29 (29.3)	12 (20.7)	–
Extremely willing	47 (47.5)	21 (36.2)	–
Casual sexual partner(s)			
Not at all willing	31 (31.3)	15 (25.9)	12.78 (4)*
Slightly willing	10 (10.1)	7 (12.1)	–
Moderately willing	29 (29.3)	6 (10.3)	–
Very willing	13 (13.1)	9 (15.5)	–
Extremely willing	16 (16.2)	21 (36.2)	–
Degree of concern about sharing PrEP adherence data with…			
Lead study physician involved in the research			
Not at all concerned	86 (86.9)	30 (51.7)	23.76 (4)***
Slightly concerned	5 (5.1)	9 (15.5)	–
Moderately concerned	4 (4.0)	8 (13.8)	–
Very concerned	1 (1.0)	2 (3.4)	–
Extremely concerned	3 (3.0)	9 (15.5)	–
Entire study team involved in the research			
Not at all concerned	73 (73.7)	28 (48.3)	16.33 (4)***
Slightly concerned	16 (16.2)	9 (15.5)	–
Moderately concerned	5 (5.1)	11 (19.0)	–
Very concerned	1 (1.0)	2 (3.4)	–
Extremely concerned	4 (4.0)	8 (13.8)	–
Primary care physician or PrEP prescriber			
Not at all concerned	72 (72.7)	25 (43.1)	16.72 (4)**
Slightly concerned	16 (16.2)	14 (24.1)	–
Moderately concerned	4 (4.0)	5 (8.6)	–

Very concerned	1 (1.0)	5 (8.6)	–
Extremely concerned	6 (6.1)	9 (15.5)	–
All healthcare providers involved in regular care			
Not at all concerned	53 (53.5)	19 (32.8)	10.56 (4)*
Slightly concerned	25 (25.3)	13 (22.4)	–
Moderately concerned	6 (6.1)	9 (15.5)	–
Very concerned	5 (5.1)	6 (10.3)	–
Extremely concerned	10 (10.1)	11 (19.0)	–

*p < .05; **p < .01; **p < .001

We also examined differences between White and POC participants on medical mistrust (Table 4). There were no significant differences between groups on the overall GBMMS score ($p > .05$). However, when each individual scale item was examined, a significant difference between White and POC participants emerged in ratings on the item, "*People like me should be suspicious of information from medical researchers*" (χ^2 (4) = 10.91, p = 0.024). A larger percentage of White participants strongly disagreed (41.4%) or disagreed (35.4%), while a greater percentage of POC (17.2%) agreed with this statement; notably, zero POC (0%) and only three (3%) White participants strongly agreed with this statement. There was also a trend toward a statistically significant difference between White and POC participants on the item, "*I do not trust medical researchers*" (χ^2 (4) = 8.65, p = 0.070). A similar pattern emerged, wherein more White participants strongly disagreed (43.4%) or disagreed (37.4%), and more POC agreed (12.1%) with the statement.

Lastly, there were also significant differences between White and POC participants in their perceptions of DPS usability as measured by the SUS (Table 4). Perceived system usability was significantly lower among POC (M=62.4, SD=19.8) than White participants (M=69.8, SD=19.9; t (119.97) = 2.26, p = 0.026). As a score of 68 on the SUS is generally considered average (Affairs, 2013), these results indicate below average perceived usability among POC, and above average usability among White participants.

Table 4. Select medical mistrust items (GBMMS) and overall perceived DPS usability (SUS) (N=157)

	White (N=99) n (%)	POC (N=58) n (%)	χ^2 (df)
GBMMS item: *I do not trust medical researchers.*			
Strongly disagree	43 (43.4)	23 (39.7)	8.65 (4)
Disagree	37 (37.4)	13 (22.4)	–
Neither agree nor disagree	13 (13.1)	14 (24.1)	–
Agree	4 (4.0)	7 (12.1)	–
Strongly agree	2 (2.0)	1 (1.7)	–
GBMMS item: *People like me should be suspicious of information from medical researchers.*			
Strongly disagree	41 (41.4)	22 (37.9)	10.91 (4)*
Disagree	35 (35.4)	14 (24.1)	–
Neither agree nor disagree	16 (16.2)	12 (20.7)	–
Agree	4 (4.0)	10 (17.2)	–
Strongly agree	3 (3.0)	0 (0.0)	–
SUS score			***t* (df)**
Mean (SD)	69.8 (19.9)	62.4 (19.8)	2.26 (119.97)*
Median [Min, Max]	72.5 [0, 100]	62.5 [20.0, 100]	–

GBMMS: Group-Based Medical Mistrust Scale.
SUS: System Usability Scale. *p < .05

4. Discussion

The present study sought to examine differences between White and POC MSM on attitudes toward DPS technology – a novel tool that allows for the objective measurement of real-time adherence to PrEP and subsequent delivery of personalized interventions

to improve adherence behavior. However, in order to make impactful progress toward achieving UNAIDS goals to end the HIV epidemic, interventions are critically needed that are effective across diverse groups. We collected survey data from adult, MSM without HIV, who self-reported substance use, current use of oral PrEP, and sexual activity in the past three months; White MSM and MSM of color were compared across variables including condom use behavior, motivations to participate in future DPS-based research, attitudes towards and concerns around sharing DPS-detected adherence data, medical mistrust, and perceived usability of DPS technology.

Our findings suggest that, while there is an overall acceptance of the DPS as an adherence measurement tool in the sample more broadly, significant differences exist between White and POC MSM surrounding potential motivations for engaging with DPS through participation in research, as well as around data sharing and privacy considerations in the DPS context. Taken together, these results indicate that key aspects of DPS acceptability that may be different across racial and ethnic groups should be carefully considered when designing research to advance adherence monitoring tools and context-aware adherence interventions.

There were statistically significant differences between White and POC participants, when examined by group, across several of these variables. By percentage, more POC than White participants reported lower willingness to share adherence data, and greater concerns related to doing so, with an entire research team, as well as with PrEP prescribers and all healthcare providers. This finding – combined with the finding that White and POC participants also differed significantly in terms of their willingness to trust information from medical researchers – suggests that community partner-based outreach, as well as substantive engagement with POC prior to initiation of DPS research, may be necessary in order to understand best practices for mitigating these barriers and building trust related to DPS acceptability and uptake in these communities.

Despite some reported concerns, POC were not completely unwilling to consider the use of DPS for PrEP adherence measurement. POC participants were more willing than White participants to share PrEP adherence data recorded by DPS with casual sexual partners, which suggests that the areas in which DPS technology is perceived to be most useful in the PrEP context may differ based on race and ethnicity. White MSM may view objective adherence data generated from DPS as a method of enhancing engagement in care, whereas MSM of color may perceive that greater benefit from DPS use can be derived in social domains (e.g., via immediate confirmation of prevention-effective adherence during casual sexual encounters). As the design of DPS continues to be refined, future DPS iterations may benefit from incorporating features that allow for customizable adherence data sharing with social contacts. Additionally, since our data suggest that MSM of color may view the primary benefits of real-time PrEP adherence monitoring in social domains, future research should explore the utility of DPS in engaging with social supports, as well as its applications in the decision-making processes regarding sexual behavior.

White and POC participants also reported differences in their motivations for potential participation in future DPS-based research studies. Significantly more POC than White participants indicated that access to free PrEP was an important motivation for participation in such research. Additionally, POC were significantly more likely to report that the opportunity to discuss PrEP adherence with a study team member would be an important motivator for participating in DPS-based research as well. Taken together, these differences suggest that POC may view participation in future studies as a means of engagement with services (e.g., access to PrEP and adherence discussions) at low or no cost; DPS-based research may therefore present an opportunity to improve engagement of MSM of color in care, while simultaneously providing a tool that can enhance PrEP adherence and decrease concerns surrounding sexual health. Moreover, DPS may represent a more accessible means by which to access healthcare interventions than is offered by current traditional adherence counseling and adherence support. Finally, because DPS-based interventions can be tailored to each user based on their personal adherence behavior, DPS may also have the potential to reduce stigma that may be associated with in-person interventions in healthcare settings (Eaton et al., 2015).

To leverage the potential benefits of using DPS, future research is needed. In the present study, POC reported significantly lower perceptions of DPS usability than did White participants. Future investigations using qualitative and/or mixed methods should be conducted in order to develop a deeper understanding of the factors that interfere with perceived system usability among POC, as well as to gain insights into suggested technological changes that could improve perceived usability for this group. Interventions to improve adherence to oral PrEP would benefit from refinements that incorporate real-time PrEP adherence data into the fabric of existing, socially accepted contexts – and particularly interventions and tools that deliver adherence skills on

a situational basis – to achieve UNAIDS goals for ending the HIV epidemic. Future research should therefore pilot DPS-informed PrEP adherence interventions among diverse samples of MSM that are tailored to each individual's adherence patterns and motivations for using PrEP.

The findings of the present study should be interpreted in the context of several limitations. First, due to low sample sizes among varying racial and ethnic groups, we combined all MSM of color into one group. Although this serves as a helpful starting point for the purposes of these analyses, it is of utmost importance to note that MSM of color are not a homogenous group, and that differences in attitudes towards DPS within specific racial and ethnic groups of MSM may exist. Though it was not possible to discern these differences in the present study (which was a secondary analysis from a larger parent study), future research should examine these groups and purposively sample to achieve statistical power in order to better understand these differences. Future research should also endeavor to obtain larger sample sizes to improve understanding of validity and generalizability. Relatedly, as indicated in Table 1, the present sample of POC is not homogenous and was comprised of a majority of individuals who identified as Hispanic or Latinx (58.6% of POC). In our sample, only 7 (12.1% of POC) individuals identified as Black and 19 (32.8% of POC) as more than one race, which did include some individuals who identified as Black as one of these races. As such, our ability to examine attitudes towards DPS among Black MSM was limited. This is an important consideration when interpreting the lack of statistical significance in overall medical mistrust found in the present study given that extant literature has shown that greater medical mistrust among Black individuals than Latinx individuals (Bazargan et al., 2021) and that medical mistrust is associated with poorer engagement in care (Brincks et al., 2019). Additionally, all data collected in this study on substance use and PrEP use were based on individual self-report, as participants were recruited via an online dating app, Grindr, outside of their healthcare establishments (where it may have been possible to confirm substance use behavior and PrEP status via medical records). Self-reported PrEP use and substance use data may have introduced reporting biases in this study. An additional source of potential bias may be present in the sampling procedures used. Those who consented to participate in this study from an app-based advertisement may be more willing to share their health information than those who read the advertisement and chose not to participate or those who did not see the advertisement. Future research should recruit participants from varied sources to reduce sampling bias.

5. Conclusion

Overall, this investigation demonstrated that, although MSM were generally accepting of DPS for PrEP adherence measurement and willing to engage in future DPS-based research, significant differences were found between White MSM and MSM of color. POC reported more concerns and less willingness around sharing DPS-detected PrEP adherence data with researchers and healthcare providers, but a greater willingness to share data with casual sexual partners, as compared to White participants. Similarly, POC reported greater frequency of condom use than White participants. POC viewed access to free PrEP and opportunities to discuss PrEP adherence as more important motivators for participation in future DPS-based research studies than did White participants. In terms of medical mistrust, POC indicated greater suspicion of medical researchers than White participants. Taken together, these findings suggest that both White MSM and MSM of color had generally favorable attitudes toward DPS for the measurement of PrEP adherence and may view the main potential benefits of DPS use for PrEP as applicable in different domains (i.e., social domains for POC vs. healthcare domains for White participants), which should inform future research on DPS usage and DPS-based interventions to improve PrEP adherence in these populations.

6. Disclosures

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