HHS Public Access

Author manuscript

Behav Sleep Med. Author manuscript; available in PMC 2021 May 01.

Published in final edited form as:

Behav Sleep Med. 2020 ; 18(3): 406–419. doi:10.1080/15402002.2019.1604344.

Changes in Sleep Quality and Associated Health Outcomes among Gay and Bisexual Men Living with HIV

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Abstract

Objectives/Background: Although gay, bisexual, and other men who have sex with men (GBMSM) bear a disproportionate burden of HIV in the U.S., they are underrepresented in HIV-related sleep research. This study sought to (a) investigate changes in self-reported sleep quality among a sample of GBMSM living with HIV during participation in an online sexual risk reduction intervention and (b) examine whether changes in sleep quality predicted later health outcomes.

Method/Participants: Men (n = 505) completed measures of sleep quality, psychological distress, condom use self-efficacy, and antiretroviral therapy (ART) adherence. Analyses focused on data obtained from participants as part of the eligibility survey, baseline assessment, and the 9- and 12-month follow-up assessments.

Results: Most participants did not report changes in their sleep quality (i.e., 50.1% maintained good sleep quality, 22.8% maintained poor sleep quality) between study screening and 9-month follow-up. Nevertheless, 17.0% indicated improved sleep quality and 10.1% indicated a negative change in sleep quality. Compared to those who maintained good sleep quality during the study, men whose sleep quality declined by 9 months reported significantly greater symptoms of depression and anxiety, as well as lower ART adherence and condom use self-efficacy at 12 months. Similarly, men who maintained poor sleep quality reported greater symptoms of depression and anxiety at 12 months. Men whose sleep quality improved reported better mental health than those with poor or worsening sleep quality.

Conclusions: Findings suggest that optimizing sleep health should be prioritized in interventions aimed at improving overall well-being of GBMSM living with HIV.

ClinicalTrials.gov: NCT02023580.

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Keywords

HIV; sleep quality; men who have sex with men; adherence; self-efficacy

Introduction

Growing evidence has connected poor or insufficient sleep to adverse outcomes among the general population in mental health (Roth et al., 2006), cognitive functioning (see Lim & Dinges, 2010 for a review), and physical health (Institute of Medicine, 2006; Irwin, Olmstead, & Carroll, 2016). The importance of sleep has received growing attention in research as it pertains to a range of health behaviors in the general population (e.g., smoking, alcohol use, and diet; CDC, 2015), and has been included in various models predicting adverse health behaviors (Barber, 2014; Hagger, 2014). It has also been recognized that sleep health is critical to the management of chronic conditions including HIV (U.S. Department of Health & Human Services, 2016).

For people living with HIV, poor sleep health has been associated with greater depression and anxiety (Allavena et al., 2016; Leyro, Babson, & Bonn-Miller, 2014; Phillips et al., 2005), poorer cognitive functioning (Byun, Gay, & Lee, 2016), poorer quality of life (Campbell et al., 2016, Rogers et al., 2018), greater inflammation (Wirth et al., 2015), and daytime fatigue (Crum-Cianflone et al. 2012). Poor sleep quality has also been shown to be associated with poorer adherence to antiretroviral therapy (ART) in people living with HIV (Babson, Heinz, & Bonn-Miller, 2013; Lee et al., 2012; Phillips et al., 2005; Saberi, Neilands, & Johnson, 2011). Many of these associations appear interconnected—for example, symptoms of depression and fatigue have been shown to mediate the association between poor sleep and poor adherence (Dalmida, Holstad, Fox, & Delaney, 2015; Phillips et al., 2005).

Further, the importance of addressing these links is heightened by findings that people living with HIV experience elevated rates of impaired sleep quality (Allavena et al., 2016; [Downing et al., 2016; Gamaldo et al., 2013; Salahuddin, Barroso, Leserman, Harmon, & Wells Pence, 2009; Wu, Wu, Lu, Guo, & Li, 2015), perhaps due to pain (Saberi, Comfort, Sheon, & Johnson, 2013), altered cortisol levels (Chrousos & Zapanti, 2014), disease progression (Lee et al., 2012), and/or psychosocial stressors such as internalized HIV stigma (Fekete, Williams, & Skinta, 2017). The startlingly high prevalence of sleep problems and fatigue among people living with HIV further underscores the importance of these associations and the need to address sleep health (e.g., Allavena et al., 2016; Phillips & Gunther, 2015; Wu et al., 2015), and particularly with regard to sexual orientation given evidence that sexual minorities experience poorer sleep relative to heterosexuals (Chen & Shiu, 2017; Fricke & Sironi, 2017; Patterson, Tate, Sumontha, & Xu, 2018).

While often addressed as a side-effect or outcome affected by disease progression, poor sleep quality has also been shown to be an important predictor of various psychosocial and behavioral outcomes among the general population that may contribute to poorer health. For example, experiencing consecutive nights of poor or insufficient sleep has been associated with increased psychological strain and reduced ability to cope with stress in the general

population (Barber & Munz, 2011). Sleep deprivation has been shown to decrease positive affect (see Ong, Bastarache, & Steptoe, 2015 for a review), to increase negative affect (Blaxton et al., 2015), and to impair the ability to regulate one's emotions (see Palmer & Alfano, 2017 for a review). Accordingly, experiencing sustained periods of poor or insufficient sleep understandably heightens the risk of poor mental health, such as depression and anxiety. The link is also complicated by the possibility that depression and anxiety can detrimentally affect the quality and duration of sleep, resulting in further diminished sleep health.

Some studies have sought to test the possible bidirectional associations between sleep and mental health (see Alvaro, Roberts, & Harris, 2013 for a review), in an attempt to disentangle the timeframes and chronology of sleep problems and changes in mental health and health behaviors. To our knowledge, the only longitudinal study to focus on sleep changes over time in people living with HIV was by Rogers et al. (2018) who found that people experiencing worse sleep (compared to their own average across numerous time points), reported lower quality of life in cognition and energy/vitality, and lower life satisfaction. The study focused on a sample of adults each presenting with depressive symptomology and enrolling in a mental health intervention study; however, the observed sleep changes did not predict depression. Nevertheless, longitudinal studies are needed to examine changes in sleep and associated health outcomes, exclusively with gay and bisexual men living with HIV.

The relevance of sleep research for the ongoing management of HIV as a chronic illness and prevention of new infections is underscored by links between poor sleep and risk-taking behavior. Research in the general population has linked sleep deprivation with increased risk-taking (see Womack, Hook, Reyna, & Ramos, 2013 for a review) and has linked poor sleep with impaired self-regulation (Barber & Munz, 2011). As an indication that this dynamic may also be influential in the realm of risk-taking in health behavior, a recent study looked at changes in smokers' sleep duration and found that those who went from having adequate to inadequate sleep duration over a 5-year period had worse dependence outcomes (Patterson, Grandner, Lozano, Satti, & Ma, 2018). Moreover, two recent studies provided evidence that rates of sexual risk-taking (i.e., condomless sex) are higher in gay and bisexual men with poor sleep quality (Duncan et al., 2016; Millar, Parsons, Redline, & Duncan, 2019a). Further, the need for sexual health researchers to consider the role of poor sleep and resulting tiredness was highlighted in recent work that connected tiredness to increased desire for sex among a sample of HIV-negative gay and bisexual men (Millar, Starks, Rendina, & Parsons, 2019b), and this resonates with earlier experimental work in which sleep-deprived college-aged males were less able to regulate their attention when viewing sexual stimuli (Zarcone, de la Pena, & Dement, 1974). Accordingly, more work is needed to study the effect of poor sleep on sexual risk and one's perceived ability to regulate their sexual behaviors.

These findings highlight the importance of addressing sleep health, especially for people living with HIV, given implications for one's ability to cope with or manage challenging situations (e.g., maintaining self-efficacy for using condoms in various scenarios such as when drunk or high, or maintaining medication adherence). In previous work, we have

shown that poor sleep quality was cross-sectionally associated with symptoms of psychological distress, lower resilience, greater substance use, and lower engagement in HIV care including medication non-adherence among a sample of gay, bisexual, and other men who have sex with men (GBMSM) (Downing et al., 2016). However, longitudinal research is needed on sleep quality and associated health outcomes in HIV-positive GBMSM, especially given that GBMSM are disproportionately affected both by poorer sleep (Chen & Shiu, 2017; Fricke & Sironi, 2017; Patterson, Tate, Sumontha, & Xu, 2018) and by elevated rates of HIV (Beyrer et al., 2016).

Accordingly, in the current study, we aimed to extend this literature by testing whether changes in perceived sleep quality (observed longitudinally between the intake screener and the 9-month follow-up) for virally-unsuppressed or sub-optimally ART adherent HIV-positive GBMSM enrolled in a behavioral intervention to address sexual risk would predict various health outcomes at the 12-month follow-up: symptoms of depression and anxiety, self-efficacy regarding condom use, and ART adherence. We hypothesized that men reporting good sleep quality at both time points, or improved sleep quality at the 9-month time point, would report experiencing fewer symptoms of depression and anxiety, greater condom use self-efficacy, and increased ART adherence at 12 months compared to those reporting bad sleep quality at both time points or worsening sleep quality at the 9-month time point.

Methods

Study Design

Sex Positive![+] is a two-arm, online randomized controlled trial (RCT) with a 1:1 allocation ratio (Hirshfield et al., 2016). The RCT tested a video-based intervention designed to reduce serodiscordant condomless anal sex and increase HIV status disclosure to sex partners. Participants were randomized to either an intervention or attention control condition. Intervention participants received a series of 10 theoretically-driven videos that addressed issues of sexual risk, HIV status disclosure, treatment adherence, substance use, and social support. Participants in the attention control condition received a series of 10 brief healthy living videos (e.g., nutrition, physical exercise, importance of sleep). Videos 1–6 were delivered weekly following the baseline assessment; 4 booster videos (or 4 additional healthy living videos in the attention control condition) were delivered weekly following the 6-month assessment. All participants completed an eligibility survey (hereafter referred to as the screener) and baseline assessment, and were invited to complete follow-up assessments every three months for one year. The current paper focuses on data obtained from participants as part of the screener, baseline assessment, and the 9- and 12-month follow-up assessments.

Participants

Interested individuals were asked to complete an online survey to determine eligibility for Sex Positive![+] (Hirshfield et al., 2016). Eligible participants for the online intervention had to: (a) be biologically male and identify their current gender as male; (b) be 18 years of age or older; (c) report their race or ethnicity as White, Black, or Hispanic; (d) report an HIV-

positive status; (e) report a past-year detectable viral load or past-month suboptimal ART adherence; (f) report serodiscordant condomless anal sex with a male partner in the past six months; (g) be able to read and respond in English; (h) reside within the United States or U.S. territories; (i) be willing to participate in an online intervention study for one year; and, (j) have a working e-mail address and cell/mobile phone number for intervention follow-up.

Recruitment

The goal of recruitment was to identify individuals online who were willing to be screened for eligibility to participate in a video-based HIV risk reduction intervention. We used quota sampling and targeted recruitment to increase representation of Black and Hispanic GBMSM as well as men between the ages of 18 and 29. This age group is overrepresented among those recently diagnosed with HIV infection, particularly young men of color, and is less likely to be adherent to HIV medications or in care (Singh et al., 2014). Men were recruited through social networking websites, sexual partnering and dating websites (e.g., BGCLive, POZ Personals), online bulletin boards, and geosocial networking applications (apps) for sexual partnering. Based on previous research findings (Sullivan et al., 2011), our targeted recruitment strategy included banner advertisements that mirrored the racial and ethnic composition of each subgroup. Banner advertisements, email blasts, and study-related postings to online bulletin boards indicated that this was a study for men living with HIV. Nearly all of the intervention participants were recruited from sexual partnering websites or Smartphone apps (96.7%).

Procedure

The institutional review board at Public Health Solutions approved all study procedures. Potential participants accessed the screener by clicking on an online study banner advertisement or study invitation link. Eligible individuals were directed to the study landing page and registration platform, which included a description of intervention activities and a consent form.

Measures

Participant characteristics. The screener included a set of demographic questions to assess age, race and ethnicity, gender identity, and sex at birth. Eligible participants who enrolled in the online intervention were asked during the baseline assessment about their highest level of education, annual income, and relationship status.

Sleep quality. We used a single item from the Pittsburgh Sleep Quality Index (PSQI) to measure subjective sleep quality (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Specifically, participants were asked as part of the screener, and again during the 9-month follow-up assessment, to rate their overall sleep quality during the past month. Response options included: very good, fairly good, fairly bad, and very bad. Responses of fairly bad and very bad on this item were considered poor sleep quality, while responses of fairly good and very good were considered good sleep quality. The use of a single item to assess subjective sleep quality has been validated in other samples (e.g., Cappelleri et al., 2009; Kuerbis et al., 2018; Perlis, Giles, Buysse, Ty, & Kupfer, 1997), and the selected item from

the PSQI was shown to be the most highly correlated of all items with the global PSQI score (Carpenter & Andrykowski, 1998).

ART adherence. We assessed any current use of antiretroviral medications (yes, no) as part of the screener, at baseline, and during all follow-up surveys. Participants also completed a 3-item validated measure of ART adherence (past 30 days) during study screening and at 6- and 12-month follow-up (Wilson, Lee, Michaud, Fowler, & Rogers, 2016). The three items assessed number of days with a missed dose, frequency of taking ART as directed, and participant's subjective rating of "how good a job" he did in taking ART as directed. The items were transformed to a 0–100 scale, with suboptimal ART adherence defined as a mean score of < 90%. The ART adherence measure had high internal consistency (Cronbach's coefficient alpha [α] = 0.83).

HIV viral load at screener. The screener included items to measure past-year viral load testing. Men who reported having a viral load test in the past year were asked to select their result from the following: My viral load was undetectable, OR < 200 copies/ml; I don't know—but I think I was undetectable; My viral load was detectable, OR > 200 copies/ml; and, I don't know—but I think I was detectable. The first two options were coded as "undetectable" and the latter two options were coded as "detectable."

Symptoms of depression and anxiety. We used the 2-item Patient Health Questionnaire Depression Scale (PHQ-2) and the 2-item Generalized Anxiety Disorder Scale (GAD-2) to measure symptoms of depression and anxiety in the past 14 days (Kroenke, Spitzer, Williams, & Löwe, 2010). Response options included: 0 (not at all), 1 (several days), 2 (more than half the days), and 3 (nearly every day). The two depression items were summed to create a score ranging from 0–6, as were the two anxiety items. All four items were administered as part of the baseline assessment and all follow-up surveys. The PHQ-2 and GAD-2 had high internal consistencies (Cronbach's α = 0.84 and 0.85, respectively).

Condom use self-efficacy. Four items asked participants about their level of confidence in their ability to use a condom for anal sex under four different circumstances: "when you feel depressed," "when you think your partner does not want to use condoms," "when you are drunk or high on drugs," and "when you are really sexually aroused." In response to each stem, participants rated their confidence on a Likert-type scale from 1 (not at all confident), 2 (not very confident), 3 (somewhat confident), 4 (very confident), to 5 (extremely confident). The four items were summed to create a total self-efficacy score ranging from 4–20. The scale was administered as part of the baseline assessment and all follow-up surveys, and had high internal consistency (α = 0.91).

Data Analysis

The ratings of past-month sleep quality reported as part of the screener and the 9-month follow-up survey generated the following four groupings of sleep quality trajectory: those who reported bad sleep quality at both time points ("Bad Sleep Quality, Maintained"), those who reported good sleep quality at screener but bad sleep quality at 9 months ("Good Sleep Quality, Worsened"), those who reported bad sleep quality at screener but good sleep quality at 9 months ("Bad Sleep Quality, Improved"), and those who reported good sleep quality at

both the screener and 9 months ("Good Sleep Quality, Maintained"). We conducted comparisons of whether these four sleep quality trajectory groupings differed on demographic characteristics (see Table 1) and on the following 12-month outcomes (see Table 2): depressive symptoms, anxiety symptoms, condom use self-efficacy (each transformed into *z*-scores and treated as continuous variables), and ART adherence (dichotomized as 0 = less than 90% adherent vs. 1 = 90% or greater adherence). Regression analyses (see Tables 3 and 4) tested whether these four sleep quality trajectories from screener to 9-month follow-up (with "Good Sleep Quality, Maintained" as the referent category) predicted the four health outcomes, while adjusting for the baseline score of each particular outcome alongside the following covariates: age, race/ethnicity (White as referent, with Black or Hispanic/Latino combined and coded as 1), study arm (Control condition as referent), relationship status (single as referent), viral load detectability at screener (undetectable as referent), education (less than a college degree as referent), and annual income (less than $20,000 as referent).

Results

During the study recruitment period, there were 16,465 completed unique screeners. Of those, 2,982 were considered eligible to participate in the intervention and a total of 1,461 individuals consented and enrolled. We excluded participants from analyses for the following reasons: 34 were disqualified by study staff (e.g., provided duplicate or fraudulent data, reported being HIV-negative, or failed survey attention/trap questions – "Please select the number 4 below. This helps prevent automated programs from abusing the study."); 208 did not complete any study activities after enrollment; 374 were not properly randomized due to a programming error; and, 15 withdrew from the study. Of the 830 HIV-positive GBMSM who were randomized into the larger study, 215 participants were missing sleep quality data at either screener or 9-month follow-up, and 110 were missing outcome data at 12-month follow-up. This left an analytic sample of 505 men (48.9% in intervention condition; 51.1% in control condition), and those excluded from analyses did not differ from those included on any screener or baseline variable of interest.

As displayed in Table 1, the majority of these 505 men were White (55.0%), single (67.9%), had an undetectable viral load (81.4%), were split across education and income groupings, and had an average age of 40.1 years ($SD = 11.2$). In terms of the four sleep quality trajectories, 22.8% of the sample had bad sleep quality at screener that remained bad at 9-months follow-up (Bad Sleep Quality, Maintained), while 10.1% had good sleep quality at screener but reported bad sleep quality at 9-months (Good Sleep Quality, Worsened), and 17.0% had bad sleep quality at screener but reported good sleep quality at 9-months (Bad Sleep Quality, Improved). The remaining 50.1% reported good sleep quality at both time points (Good Sleep Quality, Maintained). Bivariate comparisons in Table 1 show that these four groups did not differ on any of the above demographic characteristics, and that the two study conditions did not differ on sleep quality trajectory. Although not displayed in Table 1, the groups also did not differ on number of years living with HIV ($M = 10.3$, $SD = 8.4$, range 0 – 33), $F(3,498) = 0.85$, $p = 0.47$.

As displayed in Table 2, bivariate tests showed that the four sleep quality trajectory groupings differed significantly on all four health outcomes at 12-month follow-up. At 12 months, symptoms of depression and anxiety were highest and condom use self-efficacy was lowest for those whose sleep quality was bad at both screener and 9-month follow-up, as well as for those whose sleep quality, though good at screener, had become bad at 9-month follow-up. Three of the study outcomes (i.e., depression, anxiety, condom use self-efficacy) were better at 12 months for the "Good Sleep Quality, Maintained" and "Bad Sleep Quality, Improved" groups. Following a similar pattern, groups with bad sleep quality at both time points or by the 9-month mark had a greater proportion of men with sub-optimal ART adherence compared to those in the "Good Sleep Quality, Maintained" group.

At the multivariable level (Table 3), adjusting for covariates and baseline levels, both groups with bad sleep quality at 9-months ("Bad Sleep Quality, Maintained" and "Good Sleep Quality, Worsened") had greater symptoms of depression and anxiety at 12-month follow-up compared to the "Good Sleep Quality, Maintained" group. For condom use self-efficacy, both the "Good Sleep Quality, Worsened" and "Bad Sleep Quality, Improved" groups reported lower condom use self-efficacy compared to the "Good Sleep Quality, Maintained" group, after adjusting for baseline scores. The difference between the "Good Sleep Quality, Maintained" and "Bad Sleep Quality, Maintained" on condom use self-efficacy did not reach statistical significance. As shown in Table 3, study arm was not significantly associated with symptoms of psychological distress or condom use self-efficacy.

Finally, in a binary logistic regression predicting ART adherence at 12-months, the only group to differ significantly from those in the "Good Sleep Quality, Maintained" group after adjusting for covariates and adherence at study screening was the group whose sleep quality declined by the 9-month mark (Good Sleep Quality, Worsened). Specifically, men whose sleep quality declined reported significantly worse adherence at 12 months (Table 4). As shown in Table 4, study arm was not significantly associated with HIV medication adherence at the 12-month follow-up.

Discussion

The current study investigated changes in sleep quality during participation in a 12-month sexual risk reduction intervention for GBMSM living with HIV, and whether these changes predicted later depressive symptoms, anxiety symptoms, condom use self-efficacy, and ART adherence outcomes. We found that most men in this study did not report a change in their sleep quality (i.e., 50.1% maintained good sleep quality, 22.8% maintained poor sleep quality) over the period between study screening and 9-month follow-up. Nevertheless, 17.0% indicated improved sleep quality and 10.1% indicated a negative change or worsening of their sleep quality during this period. Our four sleep quality trajectory groups did not differ on sociodemographic characteristics (i.e., race and ethnicity, age, relationship status, education, income), study arm (intervention or attention control), or self-reported viral load at study screening.

Consistent with our hypotheses, findings showed that men who maintained good sleep quality or reported improved sleep quality by the 9-month follow-up period had fewer

symptoms of anxiety and depression at study conclusion (i.e., at 12 months). These results expand on previous cross-sectional research that observed significant associations between sleep quality and psychological distress symptoms (Allavena et al., 2016; Leyro, Babson, & Bonn-Miller, 2014; Phillips et al., 2005). Moreover, men in the current study who maintained poor sleep quality or indicated a negative change in sleep quality by the 9-month follow-up experienced greater anxiety and depressive symptoms at 12 months. These findings remained significant after adjusting for sociodemographic characteristics and baseline scores on outcome measures. These longitudinal findings resonate with those of Rogers et al. (2018) who observed that worsened sleep predicted lower quality of life and lower life satisfaction, though not greater depression.

Our analyses also showed that men whose good sleep quality was maintained at the 9-month follow-up indicated greater self-efficacy for condom use at 12 months compared to those whose good sleep quality worsened and those whose bad sleep quality improved. In a multivariable model adjusting for sociodemographic characteristics and baseline scores on the self-efficacy measure, compared to participants who maintained good sleep quality during the study, we observed lower self-efficacy for condom use scores among the “Bad Sleep Quality, Improved” and “Good Sleep Quality, Worsened” groups. However, the difference was not statistically significant for men who maintained poor sleep quality ($p = 0.15$). This is important given that lower self-efficacy for condom use predicted increased engagement in condomless anal sex, and mediated the relationship between syndemic factors and condomless anal sex in a recent longitudinal study of GBMSM (Safren et al., 2018). In light of previous research that poor sleep health has been linked with impaired self-regulation (Barber & Munz, 2011) and increased risk-taking behavior (Womack et al., 2013), including increased rates of substance use and condomless sex (Duncan et al., 2016; Millar et al., 2019a), our findings illuminate the detrimental effects of poor sleep quality on self-efficacy regarding sexual safety, warranting consideration in further research.

We also found that men who maintained good sleep quality were more likely to be ART-adherent at 12 months compared to men who maintained poor sleep quality or indicated a negative change in sleep quality by the 9-month follow-up. Indeed, a negative change in sleep quality by 9 months significantly predicted lower adherence to ART at 12 months after adjusting for sociodemographic characteristics and self-reported adherence at study screening. This finding adds to prior research demonstrating significant associations between sleep and ART adherence (Babson et al., 2013; Phillips et al., 2005; Saberi et al., 2011). Together, this evidence is concerning and provides support for the idea that a decline in sleep quality may disrupt one’s overall self-regulatory capacity (Millar, 2017)—although it remains unclear why reporting poor sleep quality at both time points did not predict worse ART adherence. Further research is needed to better understand psychosocial mechanisms underlying effects of sleep quality on ART adherence, and may have a significant public health impact since ART adherence is directly associated with viral suppression (Cohen et al., 2011).

Importantly, the observed differences in health outcomes by sleep quality trajectory appear to be independent of potential effects from the intervention or attention control videos. The multivariable models predicting 12-month symptoms of depression and anxiety, condom use

self-efficacy scores, and ART adherence adjusted for study arm, finding that men in the intervention arm did not differ from men in the attention control arm.

The relatively high prevalence of self-reported poor sleep quality among study participants (39.8% at study screening, 32.9% at the 9-month follow-up assessment) suggests an urgent need for sleep health interventions that target the unique needs of GBMSM living with HIV. Prior studies of interventions to improve sleep quality for people living with HIV have shown benefits of acupuncture (Phillips & Skelton, 2001) and reduced caffeine consumption (Dreher, 2003). Buchanan et al. (2018) recently reported significant improvements in sleep quality and total sleep time among a clinic-based sample of adults living with HIV following a multi-session behavioral treatment for insomnia. In addition to treatment efficacy, their intervention demonstrated high acceptability and overall feasibility. Webel et al. (2013) also demonstrated feasibility with their sleep hygiene intervention for adults living with HIV, but reported nonsignificant improvements in total sleep time, sleep efficiency, and sleep disturbances compared to a control group. Nevertheless, with the exception of Phillips and Skelton (2001), there appears to be no specific representation of GBMSM in sleep health interventions targeting those living with HIV/AIDS. There is an urgent need to implement culturally-appropriate and acceptable strategies (e.g., leverage consumer-driven regulation of sleep and other health behaviors via wearable technology; address sleep regulation in substance use treatment programs; include sleep questions with patient health screeners in HIV care settings) to improve sleep quality and related health outcomes for this population. Given the UNAIDS' 90–90-90 goal (to ensure that 90% are aware of their HIV status, that 90% of HIV-positive individuals are prescribed ART, and that 90% of individuals on ART achieve viral suppression) (UNAIDS, 2014), developing feasible interventions to improve sleep quality and reduce sleep disturbances among diverse HIV populations is critical for long-term care and preventing transmission.

Several study limitations should be acknowledged. First, causal conclusions cannot be made as the research design and intervention videos were not specifically intended to have an effect on sleep health. Second, participants were recruited primarily through sexual partnering websites or Smartphone apps and were required to have a working e-mail address and cell / mobile phone number for study participation. As such, the findings may not generalize to HIV-positive GBMSM with limited or no Internet access, who do not own a Smartphone or other mobile phone, or who do not use sexual partnering websites or apps. Moreover, MSM of color tend to be less engaged in HIV care and have lower rates of viral suppression compared to White MSM (Singh, Mitsch, & Wu, 2017). The Sex Positive![+] intervention targeted equal numbers of Hispanic / Latino, White non-Hispanic, and Black / African American GBMSM for enrollment. However, about half of the overall study sample (45% in the current analyses) included racial or ethnic minority men. Further, men of color living with HIV were less likely to remain engaged over the 12-month study period (Hirshfield et al, in press).

Third, we did not assess participant work schedules or other lifestyle factors, which may have contributed to their sleep quality throughout the study period. Fourth, the study assessed subjective sleep quality using a single-item measure administered at two time points (screening and 9-month follow-up). Further research with this population should

consider using an objective sleep measurement (e.g., actigraphy) in combination with a self-report measure of sleep quality. Although the subjective sleep quality item used in the current study has shown to be correlated with the global PSQI score (Carpenter & Andrykowski, 1998), perceived insomnia severity (Dietch et al., 2016), and sleep diary data (Dietch et al., 2016; Grandner, Kripke, Yoon, & Youngstedt, 2006), the PSQI has demonstrated few associations with objective estimates of sleep (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Grandner et al., 2006). Future studies may also consider including a validated measure of insomnia symptoms and severity, such as the Insomnia Severity Index (Morin, Belleville, Bélanger, & Ivers, 2011). The need for researchers and health care providers to more closely investigate sleep health and associated problems in people living with HIV has been advocated for by other researchers (Taibi, 2013). Lastly, we did not assess potential reasons for sleep decline or improvement during study participation.

In conclusion, our findings show that sleep quality is an important factor in the mental health, sexual health, and medication adherence of GBMSM living with HIV. Extending previous findings of cross-sectional associations between poor sleep quality and depression, anxiety, and sub-optimal medication adherence, the current study has uncovered longitudinal associations between changes in sleep quality (measured over two-time points) and health outcomes measured three months thereafter. Persistently poor or worsening sleep quality between the screener and 9-month follow-up predicted greater depressive and anxiety symptoms, as well as lower condom use self-efficacy and worse ART adherence. This is especially concerning given the well-established prevalence of poor sleep quality, sleep disturbance, and fatigue among people living with HIV (Wu et al., 2015). Encouragingly, we found that participants whose sleep quality improved by the 9-month follow-up reported comparatively better mental health and ART adherence outcomes, while those with good sleep quality at both time points reported fewer depressive and anxiety symptoms as well as the highest rates of condom use self-efficacy and ART adherence among the three groups. This suggests that optimizing sleep health should be prioritized in interventions aimed at improving overall well-being of GBMSM living with HIV.

Acknowledgments

We thank Dr. Jeffrey Parsons for comments on an earlier draft of this manuscript.

Funding

Research for this article was supported by a grant from the National Institute of Mental Health (R01MH100973, PI: Hirshfield).

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Table 1

Demographics for Sample and Comparisons by Sleep Quality (SQ) Trajectory from Screener to 9-Month Follow-Up

Demographics	Total	Bad SQ, Maintained	Good SQ, Worsened	Bad SQ, Improved	Good SQ, Maintained	Test Statistic
	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	
Overall	505 (100)	115 (22.8)	51 (10.1)	86 (17.0)	253 (50.1)	
Race and Ethnicity						
Black	120 (23.8)	18 (15.0)	9 (7.5)	24 (20.0)	69 (57.5)	$\chi^2(6) = 9.07$ $p = .17$
Hispanic/Latino	107 (21.2)	26 (24.3)	11 (10.3)	21 (19.6)	49 (45.8)	
White	278 (55.0)	71 (25.5)	31 (11.2)	41 (14.7)	135 (48.6)	
Study Arm						
Control	258 (51.1)	61 (23.6)	27 (10.5)	37 (14.3)	133 (51.6)	$\chi^2(3) = 2.71$ $p = .44$
Intervention	247 (48.9)	54 (21.9)	24 (9.7)	49 (19.8)	120 (48.6)	
Relationship Status						
Single	343 (67.9)	77 (22.4)	38 (11.1)	52 (15.2)	176 (51.3)	$\chi^2(3) = 3.57$ $p = .31$
Partnered	162 (32.1)	38 (23.5)	13 (8.0)	34 (21.0)	77 (47.5)	
Education						
Less than college	239 (47.4)	54 (22.6)	24 (10.0)	41 (17.2)	120 (50.2)	$\chi^2(3) = 0.04$ $p = .99$
College or higher	265 (52.6)	61 (23.0)	27 (10.2)	44 (16.6)	133 (50.2)	
Income						
< $20,000	152 (31.2)	41 (27.0)	16 (10.5)	31 (20.4)	64 (42.1)	$\chi^2(6) = 6.89$ $p = .33$
$20,000 - $59,999	208 (42.7)	45 (21.6)	21 (10.1)	36 (17.3)	106 (51.0)	
≥ $60,000	127 (26.1)	25 (19.7)	13 (10.2)	17 (13.4)	72 (57.7)	
HIV Detectability at Screener						
Undetectable	384 (81.4)	89 (23.2)	40 (10.4)	61 (15.9)	194 (50.5)	$\chi^2(3) = 2.54$ $p = .47$
Detectable	88 (18.6)	15 (17.0)	7 (8.0)	17 (19.3)	49 (55.7)	
	M (SD)	***M (SD)***	***M (SD)***	***M (SD)***	***M (SD)***	
Age (years)	40.1 (11.2)	40.8 (10.6)	39.8 (8.6)	38.1 (11.0)	40.4 (11.9)	$F(3,501) = 1.17$ $p = .32$

Note. SQ = Sleep Quality.

Table 2

Comparisons by Sleep Quality Trajectory (from Screener to 9-month follow-up) on Outcomes (at 12-month follow-up)

Outcomes	Total, *N* = 505	Bad SQ, Maintained (a)	Good SQ, Worsened (b)	Bad SQ, Improved (c)	Good SQ, Maintained (d)	Test Statistic
	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	
Depression	1.44 (1.8)	2.34 (2.1)	1.90 (1.9)	1.29 (1.5)	0.99 (1.5)	$F(3,500) = 18.39^{***}$
Anxiety	1.37 (1.7)	2.27 (2.1)	1.96 (1.8)	1.33 (1.6)	0.84 (1.3)	$F(3,500) = 22.20^{***}$
Self-efficacy for Condom Use	10.98 (4.9)	10.17 (4.6)	8.79 (4.7)	11.02 (4.9)	11.74 (5.0)	$F(3,446) = 5.72^{**}$
Medication Adherence:	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	
Suboptimal (<90%)	232 (45.9)	66 (57.4)	31 (60.8)	41 (47.7)	94 (37.2)	$\chi^2(3) = 18.57^{***}$
90% or higher	273 (54.1)	49 (42.6)	20 (39.2)	45 (52.3)	159 (62.8)	

Note. SQ = Sleep Quality.

** $p < .01$;

*** $p < .001$. Pairwise comparisons of estimated marginal means were used to indicate significant differences within rows at $p < .05$: Anxiety (a > c, d; b > c, d; c > d), Depression (a > c, d; b > c, d), and Self-efficacy for Condom Use (a < d; b < c, d). Fisher's exact test was used to test for significant within row differences in Medication Adherence: a, b > d.

Table 3

Linear Regressions Predicting Mental Health Outcomes (at 12-month follow-up) from Sleep Quality Trajectory, N = 505

	Outcome 1: Depression			Outcome 2: Anxiety			Outcome 3: Self-Efficacy for Condom Use		
	ARR	***p***	**95% CI**	**ARR**	***p***	**95% CI**	**ARR**	***p***	**95% CI**
Constant	1.11	.34	[0.89, 1.38]	1.03	.82	[0.83, 1.27]	0.82	.10	[0.65, 1.04]
Age	1.00	.69	[0.99, 1.01]	1.00	.90	[0.99, 1.01]	1.00	.81	[0.99, 1.01]
Race and Ethnicity (ref. White)									
Black or Hispanic/Latino	**0.85**	**.05**	**[0.73, 1.00]**	0.91	.26	[0.78, 1.07]	**1.27**	**<.01**	**[1.07, 1.51]**
Study Arm (ref. Control)									
Intervention	1.10	.21	[0.95, 1.29]	1.12	.14	[0.96, 1.30]	1.10	.25	[0.93, 1.31]
Relationship Status (ref. Single)									
Partnered	0.86	.08	[0.73, 1.02]	0.96	.65	[0.82, 1.13]	1.17	.10	[0.97, 1.40]
Viral Load at Screener (ref. Undetectable)									
Detectable (≥200 copies)	1.06	.58	[0.87, 1.29]	1.06	.55	[0.87, 1.29]	1.15	.19	[0.93, 1.43]
Education (ref. Less than college)									
College degree or more	0.87	.10	[0.74, 1.03]	0.90	.20	[0.76, 1.06]	1.04	.71	[0.86, 1.24]
Income (ref. less than $20K)									
$20K - $49,999	0.93	.46	[0.77, 1.12]	0.88	.16	[0.73, 1.06]	1.16	.14	[0.95, 1.42]
$50K or more	0.87	.22	[0.69, 1.09]	0.84	.12	[0.61, 1.05]	1.01	.91	[0.79, 1.30]
Baseline Score on Outcome*	**1.32**	**<.001**	**[1.26, 1.39]**	**1.34**	**<.001**	**[1.27, 1.40]**	**1.10**	**<.001**	**[1.08, 1.12]**
SQ (ref. Good SQ, Maintained)									
Bad SQ, Improved	1.00	.99	[0.80, 1.24]	1.01	.91	[0.82, 1.26]	**0.73**	**<.01**	**[0.57, 0.92]**
Good SQ, Worsened	**1.55**	**<.01**	**[1.19, 2.01]**	**1.54**	**<.01**	**[1.19, 2.00]**	**0.69**	**.02**	**[0.51, 0.94]**
Bad SQ, Maintained	**1.58**	**<.001**	**[1.30, 1.93]**	**1.51**	**<.001**	**[1.24, 1.83]**	0.86	.15	[0.70, 1.06]
Model Statistics:	Model $\chi^2(12) = 181.05$ $p < .001$			Model $\chi^2(12) = 189.01$ $p < .001$			Model $\chi^2(12) = 141.25$ $p < .001$		

Note. SQ = Sleep Quality; ARR = adjusted rate ratio; CI = confidence interval; ref. = referent. Bolded results are significant at $p < .05$ or less. Depressive and anxious symptoms assessed at baseline and 12-month follow-up using the PHQ-2 and GAD-2 (Kroenke et al., 2010).

Table 4

Logistic Regression Predicting Medication Adherence (at 12-month follow-up) from Sleep Quality Trajectory, N = 505

	Medication Adherence		
	AOR	***p***	**95% CI**
Constant	0.83	.56	[0.44, 1.55]
Age	1.00	.92	[0.98, 1.02]
Race and Ethnicity (ref. White)			
Black or Hispanic/Latino	0.79	.34	[0.49, 1.28]
Study Arm (ref. Control)			
Intervention	0.69	.12	[0.43, 1.10]
Relationship Status (ref. Single)			
Partnered	0.99	.98	[0.61, 1.62]
Viral Load at Screener (ref. Undetectable)			
Detectable (≥200 copies)	0.83	.60	[0.42, 1.65]
Education (ref. Less than college)			
College degree or more	1.47	.13	[0.89, 2.43]
Income (ref. less than $20K)			
$20K - $49,999	1.15	.63	[0.66, 2.01]
$50K or more	1.12	.74	[0.58, 2.15]
SQ (ref. Good SQ, Maintained)			
Bad SQ, Improved	0.96	.90	[0.50, 1.82]
Good SQ, Worsened	**0.31**	**<.01**	**[0.13, 0.72]**
Bad SQ, Maintained	0.71	.23	[0.40, 1.25]
Adherence at Screener (ref. Suboptimal)			
Adherent (≥90% on Wilson)	**7.16**	**<.001**	**[3.55, 14.44]**
Model Statistics:	Model $\chi^2(12) = 58.58$, $p < .001$ Percent correctly classified: 64.5% Nagelkerke's $R^2 = .20$		

Note. SQ = Sleep Quality; AOR = adjusted odds ratio; CI = confidence interval; ref. = referent.

Medication adherence assessed at study screening and 12-month follow-up using a 3-item self-report measure (Wilson et al., 2016).

Bolded results are significant at $p < .05$ or less.