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Race and Residential Socioeconomics as Predictors of CPAP Adherence

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Study Objectives: There are few established predictors of CPAP adherence; poor adherence limits its effectiveness. We investigated whether race, education level, and residential economic status predict CPAP adherence in participants enrolled in a trial with standard access to treatment.
Design: A multi-center randomized trial of home vs. lab-based evaluation and treatment of OSA assessing adherence to CPAP at 1 and 3 months.
Setting: Seven AASM-accredited sleep centers in 5 U.S. cities.
Participants: Subjects with moderate to severe OSA (AHI ≥ 15 and Epworth Sleepiness Scale score > 12) who completed follow-up at 1 and/or 3 months (n = 135).
Measurements and Results: Subjects' demographic data were collected upon enrollment; CPAP use at 1 and 3 months was assessed at clinic follow-up. In unadjusted analyses, CPAP adherence (average minutes per night of CPAP use) at 3 months was lower in black subjects and in subjects from lower socioeconomic status ZIP codes. In adjusted analyses using multivariate linear regression, black race was predictive of CPAP adherence at one month (P = 0.03). At 3 months, black race was predictive in analyses only when ZIP code SES was not adjusted for.
Conclusion: Black race and lower socioeconomic residential areas are associated with poorer adherence to CPAP in subjects with standardized access to care and treatment. Disparities remain despite provision of standardized care in a clinical trial setting. Future research is needed to identify barriers to adherence and to develop interventions tailored to improve CPAP adherence in at risk populations.
Portable Monitoring for Diagnosis and Management of Sleep Apnea (HomePAP)
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INTRODUCTION

Obstructive sleep apnea (OSA) is a common disorder characterized by recurrent upper airway collapse during sleep. OSA is associated with cardiovascular disease and increased mortality.[1-4] OSA syndrome, defined as OSA with daytime sleepiness, has a worldwide prevalence of 2% to 5%,[5] and may differ across racial and ethnic groups.[6,7] Continuous positive airway pressure (CPAP) is an effective treatment for OSA, eliminating obstructive events, nocturnal hypoxemia and reducing nocturnal arousals.[8] It is associated with lower cardiovascular disease mortality.[1,9] CPAP use also improves sleep and quality of life and reduces daytime sleepiness.[10] Yet, adherence with this therapy remains poor, with only half of patients using CPAP for more than 4 hours per night.[11] Determinants of CPAP adherence are not well understood with conflicting results from various studies.[12]

Factors that co-vary with demographic factors, such as race, ethnicity, and socioeconomic status (SES), may contribute to CPAP adherence. Individuals with low SES and those of minority race/ethnicity have higher levels of obesity, physical inactivity, alcohol consumption, smoking,[13,14] and poor medication compliance[15]; these health behaviors may correlate with CPAP adherence. For example, lower statin medication compliance has been associated with lower CPAP use, suggesting that medication and CPAP adherence may be correlated.[16] Barriers to adherence in low SES groups may include low health literacy, competing needs with limited resources, and limited access to care.[17]

Minorities and low SES groups may be at risk for more severe OSA than more affluent populations, possibly due to environmental exposures that increase inflammation or cause sleep disruption. The notion is supported by findings showing low SES neighborhood residence increases the odds of OSA in children approximately 3-fold.[18] Recent data suggest that ambient pollution, higher in poor urban areas, is associated with sleep apnea severity in adults.[19] Low SES and minority populations have a greater burden of comorbidities associated with OSA, such as poorly controlled diabetes, hypertension, obesity, stroke,[20-22] and higher cardiovascular mortality,[23-25] which may place these groups at particular risk for OSA-related morbidity. Among subjects with OSA, low SES is an independent risk factor for cardiovascular disease.[26] Retrospective studies have found a higher prevalence of comorbid disease and lack of follow-up in underinsured and minority OSA subjects.[17] Thus optimizing CPAP adherence in these populations is of critical importance.

Relatively few studies have investigated the contribution of demographic factors to CPAP use. Race and ethnicity have

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been associated with CPAP adherence in some, but not all, studies.[27-29] Only a few of these studies comprehensively adjusted for socioeconomic status, which is also associated with CPAP adherence.[30,31] Prior reports have been predominantly retrospective cohort studies from single centers.

We hypothesized that social factors including race/ethnicity, education, and residential socioeconomic status would be predictive of CPAP adherence in subjects enrolled in a multicenter trial who received standardized CPAP treatment for moderate-severe OSA. A better understanding of CPAP adherence in participants in clinical trials was of particular interest, given the need to design informative clinical trials that include minority populations.

METHODS

Participants

The subjects included in this analysis (n = 191) were enrolled in the *HomePAP* study, a randomized controlled trial comparing unattended home diagnosis of OSA and titration of CPAP to attended lab-based care with respect to CPAP adherence and other outcomes. Subjects were recruited from 7 AASM-accredited sleep centers in 5 cities (Seattle, Chicago, Madison, Minneapolis, and Cleveland [3 sites]). Subjects were eligible if they had a high probability of moderate to severe sleep apnea based on a clinical algorithm including neck circumference, hypertension, habitual snoring, witnessed apneas, and choking or gasping. Additionally all subjects had a minimum Epworth Sleepiness Scale (ESS) score of 12. Subjects were excluded if they had underlying lung disease, an unstable medical condition, chronic narcotic use, alcoholism, a comorbid sleep disorder such as narcolepsy or moderate restless leg syndrome, or were planning on undergoing bariatric surgery. Study site coordinators obtained informed consent from each subject prior to enrollment. The study protocol and procedures were approved by human subjects divisions and internal review boards at each participating institution.

Procedure

Eligible subjects completed questionnaires assessing demographic data, medical comorbidities, medication use, and baseline sleepiness (ESS). Upon enrollment, trained personnel measured height, weight, and blood pressure. Eligible subjects were randomized to either home or lab-based studies. Prior to determining eligibility for CPAP, all subjects received standardized education regarding sleep apnea, sleep hygiene, and CPAP for OSA including a tutorial by each site's study coordinator, a personalized mask fitting, and educational brochures produced by the AASM. The lab-based polysomnography montage was standardized; both home and lab-based studies were scored at the coordinating center (Case Western Reserve University) in a blinded fashion according to AASM criteria (including the standard definition for hypopnea). Home-based studies were performed using EmblaX-30 device.

Subjects with an apnea hypopnea index (AHI) $\geq$ 15 qualified for the study and underwent CPAP titration studies. If subjects had an AHI < 15 on a technically satisfactory home study, they crossed over to the lab arm for confirmatory polysomnogram. Subjects in the home arm performed a 5- to 7-night home auto-CPAP titration procedure with Respironics REMstar Auto-M series with C-flex. For these subjects, fixed CPAP pressure setting was based on the pressure that was sufficient to control OSA 90% of the time on nights with acceptable leak on the auto-CPAP download. Lab-based subjects had a CPAP titration in the lab according to AASM guidelines. All qualifying subjects were offered CPAP at a set pressure. CPAP machines and supplies were provided at no cost to the subjects. All subjects received a standardized telephone contact one week after starting CPAP by study staff for troubleshooting and optimizing utilization. Subjects followed up in clinic at 1 and 3 months; their CPAP data were downloaded. Factors limiting adherence were addressed by a sleep specialist according to AASM guidelines.

Analysis

We performed descriptive analysis of all subjects eligible for CPAP comparing predictors and covariates. Our primary predictors of interest were self-reported race/ethnicity, level of education, employment status, and ZIP code socioeconomic status (SES). We created a ZIP-code SES summary score based on prior studies[18,30,32,33] incorporating several SES variables: median household income, percent high school and college graduates of the population over 25 years, percent of families below poverty level, percent unemployed, and percent in managerial or professional occupations. These SES data were obtained from 2000 US census data using subjects' ZIP code at enrollment.[34,35] Each SES variable was standardized to a Z-score (subtracting mean and dividing by standard deviation for each SES factor). A higher SES summary score reflected a higher ZIP code SES in our sample.

We explored the association of our predictors with each other and *a priori* determined pertinent covariates including age, gender, smoking status, marital status, BMI, baseline ESS, CPAP set pressure, AHI, and study arm. AHI was evaluated categorically by quartile. We assessed the association with our predictors and our main outcomes, CPAP adherence at 1 and 3 months (average daily use in min), in bivariate analyses. Education was dichotomized by $\leq$ high school or equivalent degree or higher. ZIP code SES was dichotomized by the lowest quartile SES summary score vs. other quartiles.

Finally we used multivariate linear regression to evaluate if our predictors (race/ethnicity, employment status, education level, and ZIP code SES) were associated with CPAP adherence at 1 and 3 months. We evaluated age, gender, smoking status, marital status, BMI, baseline ESS, CPAP set pressure, AHI, and study arm (home vs. lab) as covariates. Variables were included in the model if they changed the β of the significant predictors of interest by 10% or were significant ($P < 0.10$) predictors of CPAP use. Only race, ZIP code SES, AHI, and study arm met these criteria and were included in the final regression models. Education level and employment status were not significant predictors, nor did they impact the other predictors. Due to the high co-linearity of ZIP code SES and race, we also performed separate regressions, each partially adjusted: not including race/ethnicity in one model and separately unadjusted for ZIP code SES in another.

RESULTS

A total of 373 patients were enrolled in the study and randomized to either lab or home-based evaluation. Of those, 191

met eligibility requirements (AHI ≥ 15) and remained in the study. The majority of eligible subjects were men (65%), obese with severe OSA (AHI mean 43 [26.1]) (Table 1A). The subjects were relatively diverse: 62% white, 22% black, and 9% Hispanic. By comparison, the US population is 13% black and 16% Hispanic.[35] The subjects lived in ZIP codes slightly above US national median income with lower poverty rates compared to national levels (Table 1B).[34]

Ninety-one percent accepted CPAP and began using the device. Acceptance was lower in subjects from the lowest quartile SES ZIP codes compared to other quartiles (83% vs. 94%, $P < 0.001$) and in black compared to non-black subjects (83% vs. 94%, $P < 0.001$). Eighteen subjects withdrew after diagnosis but prior to receiving CPAP; 16 withdrew after receiving their CPAP but prior to one month follow-up; 145 subjects returned for follow-up at one month and 135 at 3 months. Those not completing 3 months follow-up were less educated, more likely to be black, and from lower SES ZIP codes.

Our predictors of interest (race, education, and ZIP code SES) were highly correlated. Black subjects were more likely to live in the lowest quartile SES ZIP codes and have only a high school degree than white and Hispanic subjects (Table 2A). Subjects with no more than a high school degree were more likely to live in a low SES ZIP code. The majority of subjects from the lowest SES ZIP codes were of black race (59%) (Table 2B). The severity of sleep apnea (baseline ESS, AHI) and CPAP pressure did not significantly differ by these demographic factors.

Overall CPAP use at 3 months was a mean 254 min/night (4.2 h/night). In bivariate analyses, CPAP use at one and three months differed by race (black vs. white/Hispanic), high school education level and ZIP code SES score (Table 3). Subjects with only a high school degree used CPAP for 56 min less nightly compared to those with more education at 1 month ($P = 0.03$, unadjusted). Among subjects from the lowest quartile SES ZIP codes, white subjects (n = 11) used CPAP for 245 min (4.1 h) vs. 146 min (2.4 h) in black subjects (n = 15) but the difference was not statistically significant in this small sample ($P = 0.08$).

Black race was the only significant predictor of CPAP use at one month (Table 4). On average, black subjects used CPAP 92 minutes less than white subjects after adjustments. Employment status, education level, age, gender, BMI, smoking and marital status, CPAP pressure, and ESS were not associated with the outcome and did not affect the predictors. Therefore none of these variables were included in the regression models. At 3 months, when not adjusting for SES, black race was predictive of CPAP use (Table 5, Model 1). Only highest quartile AHI and study arm were predictive of CPAP use with complete adjustment (Model 2). Lowest quartile ZIP code SES score was not significant but did impact the association of race and CPAP use. Race explained 6% to 12% of the variance (partial R^2 of 0.06-0.12) in CPAP use at 1 and 3 months. Interaction terms for black race/ZIP code SES and race-study/arm were not significant.

DISCUSSION

In a randomized controlled trial with a protocol that sought to provide standardized CPAP treatment to all participants, CPAP adherence was lower in subjects of black race and from lower socioeconomic status ZIP codes. This study provides strong evidence that demographic factors influence adherence patterns. CPAP adherence differed significantly by race at 3 months but not by other social factors such as education, employment, marital or smoking status. After adjustments for disease severity, treatment arm, ZIP code SES, black race predicted a clinically significantly lower mean nightly use at one month of over one hour. These findings suggest that despite attempts to standardize access, treatment and follow-up care, inequities remain. The underlying etiology for these observed differences remains to be determined, but is likely associated with the complex socioeconomic-environmental factors that are linked to both race and SES.

Table 1A—Baseline characteristics of HomePap subjects eligible for CPAP

Eligible Participants	**N = 191**
Age, mean (SD)	48 (12)
% Male (n)	65 (124)
BMI mean (SD)	38.4 (8.7)
% Race/Ethnicity (n)	
White, non-Hispanic	62 (119)
Black	22 (42)
Hispanic	9.4 (18)
Other	6.3 (12)
% Smoker (n)	10 (19)
% Married (n)	60.3 (114)
% Unemployed (n)	14.7 (28)
% Education (n)	
High school or less	22 (42)
Vocational degree/courses	17.4 (33)
Some college	19.5 (37)
College degree	23.7 (45)
Advanced degree	17.4 (33)
Sleep Traits, mean (SD)	
Baseline ESS	14.3 (3.7)
AHI	43.2 (26.1)
Optimal titration pressure	10.7 (2.9)

SD, standard deviation.

Table 1B—The socioeconomics of HomePap subjects' ZIP codes

Participants' ZIP Code Socioeconomics	**median (IQR)**
Median Household Income	$43,000 (37-55,000)
% Unemployed of population > 16 y in labor force	3.6 (2.5-5.5)
% Families below poverty	6.5 (3.5-15.5)
% High school graduates of population > 25 y	84.6 (76.7-91.7)
% College graduates of population > 25 y	25.1 (13.7-37.0)
% Managerial/professional occupation of civilian employed population > 16 y	33.9 (25.3-42.5)

IQR, interquartile range.

Table 2A—HomePap subjects characteristics stratified by race (n = 191)

	White Non-Hispanic N = 119	Black Non-Hispanic N = 42	Hispanic N = 18	P-value*
Age- years mean (SD)	**50 (12.6)**	**44 (10.0)**	**46 (12.1)**	**0.03**
BMI mean (SD)	38 (8.6)	40.8 (8.7)	38.0 (8.2)	0.17
Smoker %	**6.8**	**25.6**	**0**	**0.003‡**
Married %	**69**	**40.5**	**55.6**	**0.006†**
> High school education %	**85.6**	**54.8**	**77.8**	**< 0.001†**
Unemployed %	15.5	20.5	5.6	0.51
Lowest quartile SES ZIP code %	**11.4**	**65.6**	**23.5**	**< 0.001**
ESS mean (SD)	14.5 (3.4)	13.7 (4.4)	13.8 (3.6)	0.66
CPAP pressure	10.5	11.2	10.7 (2.9)	0.76
AHI mean (SD)	44.5 (27)	39.2 (25.7)	46.3 (26.1)	0.62

Table 2B—Subjects' characteristics by ZIP code SES summary score quartiles

SES Summary Score	Lowest Quartile N = 46	Quartiles II-IV N = 137	P-value
Age- years mean (SD)	45.4 (10.2)	48.5 (13.0)	0.09
BMI mean (SD)	**41.2 (8.7)**	**37.7 (8.7)**	**0.02**
Smoker %	**28.0**	**5.3**	**< 0.001**
Married %	**39**	**66**	**0.002**
> High school education %	**56.5**	**84.0**	**0.001**
White race %	**28**	**74**	**< 0.001**
Black race %	**59**	**10**	**< 0.001**
Unemployed %	23.3	11.4	0.10
ESS mean (SD)	14.8 (4.1)	14.1 (3.6)	0.25
CPAP pressure	11.1 (2.5)	10.7 (3.0)	0.34
AHI mean (SD)	42.6 (27.8)	43.7 (26.0)	0.81

*ANOVA. Tukey post hoc analysis: †significant black vs. white. ‡Significant black vs. white & black vs. Hispanic. **Bolded** values are significant (P < 0.05).

The association between black race and CPAP adherence is supported by results from prior studies. An observational cohort study from an urban Chicago sleep clinic with predominantly black uninsured subjects found black race predicted lower adherence.[28] CPAP adherence assessed at a Detroit sleep center was also less in black vs. white subjects.[29] However, an observational study at the University of Maryland found no difference by race in CPAP acceptance and self-reported compliance (not objectively assessed).[27] These studies were limited, as they did not adjust for socioeconomic status and included routine rather than standardized care. They all similarly relied on observational data from one center with limited socioeconomic diversity of subjects. Our study findings are enhanced by our subject population, who are from diverse geographic, racial/ethnic, educational backgrounds, and ZIP code SES, and who received standardized evaluation and treatment.

Our results are also supported by prior cohort studies demonstrating an association of SES and CPAP adherence. In bivariate analysis, CPAP use was lower in subjects from the lowest quartile SES ZIP codes, despite the mitigation of some factors contributing to treatment disparities by virtue of trial participation. A study of US veterans in Philadelphia showed only 34% of veterans from the lowest socioeconomic neighborhoods used CPAP > 4 hour/night compared to 62% in the highest SES neighborhoods.[30] In that study, there was no difference by race in CPAP adherence, even in crude analysis. In Israel, studies have shown higher CPAP acceptance among subjects with higher monthly income[31,36] and by neighborhood SES.[36] In the Israeli studies, CPAP acceptance required purchase, explaining some of the association with income. Ethnicity was not evaluated in the Israeli studies. Among Chinese patients with overall high adherence, disadvantaged subjects receiving CPAP by government aid (presumed low SES) had lower usage, although this did not reach statistical significance.[37] ZIP code SES confounded or perhaps was in the causal pathway of the association of race and CPAP use. It was not a predictor in adjusted models, likely due to suboptimal power.

Our study findings are strengthened by the use of prospective data from subjects receiving standardized evaluation and treatment. The subjects were uniformly symptomatic with significant sleepiness, and all had at least moderate sleep apnea. The effects of insurance, cost of equipment and follow-up care, access to treatment were minimized by enrollment in a treatment study. Additionally, including subjects from 5 different cities and 7 sites mediated the effects of site-specific differences and provided geographic diversity. The use of standardized protocols of scoring and treatment further enhanced our findings. Thus, our results are less likely to be simply due to systems issues such as differences in insurance, health system financing, and clinic organization, and are more likely due to other factors associated with our predictors. Our findings demonstrate the importance of including a diversity of race and SES in randomized controlled trials evaluating CPAP use.

However, the study also has important limitations. The adjustment for socioeconomic status was incomplete and did not have optimal spatial resolution due to the use of ZIP code rather than personal addresses to reflect neighborhood SES. ZIP code designates a large geographic area that often lacks homogeneous socioeconomic characteristics. The ZIP code SES status provides information on residential socioeconomic characteristics but does not provide household-specific data on personal income or economic resources. As measuring SES was not an aspect of the initial study design, factors such as health literacy and personal income were not collected. Instead, we used several markers of SES, ZIP code demographic information, individual education level, and employment status. Due to the imprecision of some of these measurements, it is likely

Table 3—CPAP adherence outcomes stratified by race and ZIP code SES quartile among subjects enrolled in the HomePap study (n = 145 1 month, n = 135 3 months)

Race	Black Non-Hispanic	White Non-Hispanic	P-value†
% days > 4 h CPAP use (1 month) mean (SD)	35.8 (28.6)	55.6 (31)	0.004
% days > 4 h CPAP use (3 months) mean (SD)	41.2 (30)	60 (33)	0.02
Average nightly use in min (1 month) mean (SD)	151 (103)	256 (130)	< 0.001
Average nightly use in min (3 month) mean (SD)	179 (106)	267 (141)	0.007
ZIP Code SES Summary Score Quartile	**Lowest Quartile**	**Quartiles II-IV**	**P-value†**
% days > 4 h CPAP Use (1 month) mean (SD)	46.0 (33)	51.5 (31)	ns
% days > 4 h CPAP Use (3 months) mean (SD)	44.5. (34)	58.2 (32)	ns
Average nightly use in min (1 month) mean (SD)	203.7 (136)	238.1 (128)	ns
Average nightly use in min (3 month) mean (SD)	197.4 (143)	259.2 (133)	0.05

†Unadjusted T-test.

Table 4—Outcome of CPAP adherence at one month (average min/day) using multivariate linear regression in HomePAP subjects

Predictor	ß	SE	P
Black Race*	**-92.2**	**32.7**	**0.006**
Hispanic*	-3.8	37.4	0.92
Lowest Quartile ZIP code SES	11.2	30.7	0.72
AHI II† (20.8-34.5)	-0.42	31.3	0.99
AHI III† (34.6-62.0)	49.2	30.9	0.11
AHI IV† (> 62.0)	*59.2*	*31.5*	*0.06*
Study Arm: Home	31.8	22.1	0.15

*Referent white, non-Hispanic; †referent AHI lowest quartile (< 20.7). N = 137, R^2 = 0.14, P = 0.006; AHI, apnea hypopnea index; SES, socioeconomic status. **Bolded** values are significant (P < 0.05); *italic* values P < 0.10.

Table 5—CPAP adherence at 3 months utilizing different multivariate regression models

Predictor	Model 1	Model 2	Model 3
Black race*	**-87.9**	*-68.5*	–
Hispanic*	21.5	26.7	–
Lowest Quartile ZIP code SES	–	-22.8	*-49.7*
AHI II† (20.8-34.5)	-3.2	1.8	1.4
AHI III† (34.6-62.0)	33.3	46.8	54.5
AHI IV† (> 62.0)	**69.3**	**80.0**	**88.9**
Study Arm: Home	**73.7**	**63.9**	**56.8**

Beta values are shown and represent difference in minutes of CPAP use per night for each predictor compared to its reference variable. **Bolded** values are significant (P < 0.05); *italic* values P < 0.10. *Referent white, non-Hispanic; †referent AHI lowest quartile (< 20.7). Model 1: Adjusted for black race, Hispanic ethnicity (referent white non-Hispanic), apnea hypopnea index (AHI) by quartile (referent lowest quartile AHI < 20.7) and study arm (referent lab arm); N = 135, R^2 = 0.17, P < 0.001. Model 2: Model 1 plus lowest quartile ZIP-Code socioeconomic status (SES) (referent quartiles II-IV of ZIP code SES summary score); N = 129, R^2 = 0.18, P = 0.001. Model 3: Model 1 without race/ethnicity but with lowest quartile ZIP code SES; N = 129, R^2 = 0.14, P = 0.002.

that analyses that examined the association between race and adherence may have been limited by residual confounding by SES. Our sample of 135 subjects studied at 3 months is also underpowered to detect a difference in CPAP use at 3 months follow-up; this is further reduced by a greater loss to follow-up of black and lowest SES ZIP code subjects. We also did not adjust for clinic site which, despite attempts to standardize care, may have impacted the results. Finally, the lack of diversity of race by SES with the preponderance of black subjects residing in low income ZIP codes substantially limited our ability to simultaneously evaluate both factors in our regression. Thus, the results did not allow us to reach any conclusions as to whether race is independently associated with CPAP adherence.

The noteworthy finding of our study was that despite standardized therapy, disparities in CPAP use were large. The ability to implement treatments that require high levels of self-management and self-efficacy may contribute to observed differences in use. Economics can affect a subject's ability to get transportation, time off from work, and childcare to attend to health needs. Low SES and minority subjects may sleep fewer hours[38] or simply lack a way to easily use their CPAP due to bedroom limitations. Community attitudes about the benefits of CPAP could differ; social and cultural beliefs towards health care and sleep may affect acceptance and use of CPAP. Health behaviors associated with low SES and minority status, such as heavy alcohol consumption or cigarette smoking,[14] may be associated with lower CPAP adherence. A lower health literacy among minorities and low SES subjects[39] may also reduce adherence as the benefits of treatment are not completely realized; the cumbersome nature of CPAP treatment may be more overwhelming.

In summary, this study demonstrates that race is associated with CPAP use in subjects receiving standardized care. A larger pool of subjects with greater diversity of race and SES is needed to verify these findings with complete adjustment. Future studies are also needed to investigate possible contributors to these observed differences such as health literacy, cultural beliefs, sleep opportunity, and community factors. Understanding the basis for observed differences in CPAP use is necessary to design appropriate interventions to improve adherence in at risk populations.

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