


Undetectable=Untransmittable Perception and Its Association with Sexual Risk Behaviors and Potential Physical and Psychological Benefits Among People Living with HIV/AIDS in Hunan, China

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Purpose: Undetectable = Untransmittable (U=U) is the scientific consensus that people living with HIV (PLWH) who maintain an undetectable viral load cannot sexually transmit HIV to others. This study aimed to explore the status of PLWH's perception of U=U (including knowledge, attitude, and acceptance) and the relationships with their sexual behaviors and potential physical and psychological benefits (satisfaction of health, depression, self-stigma, quality of life, ART adherence, viral load and CD4+ cell level).

Patients and Methods: We analyzed data from 730 PLWH aged 18 years or older from the outpatient clinic at the Affiliated Changsha Hospital of Xiangya School of Medicine, Central South University, between October 2021 and January 2022. Data were collected using a structured, anonymous, paper-based questionnaire. It gathered information on U=U perception, sexual risk behaviors, potential physical and psychological benefits and socio-demographic and clinical characteristics. To examine associations between U=U perception and sexual risk behaviors and potential physical and psychological benefits, for categorical outcome variable, multiple logistic regression was adopted for the CD4+ cells and HIV viral load level; for count outcome variable, generalized linear model (GLM) with Poisson regressor was used for sexual risk behaviors; and since all the other response variables were skewed, GLM with Gamma regressor was used.

Results: The mean age of the participants was 33.6 years (SD = 10.8). Majority (95.1%) of the participants were male and initiated ART (97%). Nearly half had bachelor's degree or higher (45.6%) and were identified as homosexuality (48.5%). More than half heard U=U (63.8%) and perceived U=U accurate (57.4%), however only 13.6% had a comprehensive understanding of U=U and 19.9% accepted U=U as a strategy for HIV prevention. The acceptance level of U=U was positively correlated with increased unprotected sexual behaviors [β (95% CI)=0.21(0.045,0.365); $P<0.05$]. The U=U perception was not related to depression, antiretroviral therapy adherence, self-stigma and perceived quality of life. We only found that less U=U knowledge was associated with the detectable [β (95% CI)=0.69(0.503,0.903); $P<0.05$] or unavailable viral load [β (95% CI)=0.68(0.0528,0.884); $P<0.01$], and unavailable CD4+ cell counts was more like to less U=U knowledge [β (95% CI)=0.62(0.395,0.959); $P<0.05$]. Furthermore, those with unavailable viral data exhibited a more negative attitude towards U=U [β (95% CI)=0.79(0.635,0.977); $P<0.05$]. In addition, lower level of U=U acceptance was related to the unavailable CD4 cell counts [β (95% CI)=0.67(0.474,0.940); $P<0.05$].

Conclusion: This study suggests that PLWH have not fully reaped the benefits of U=U. Further research is necessary to explore strategies for promoting clear and accurate information about U=U and for effectively communicating the personal and societal benefits of U=U to PLWH.

Keywords: undetectable = untransmittable, knowledge, attitude, acceptance, sexual behaviour, potential physical and psychological benefits

Introduction

People living with HIV/AIDS (PLWH) benefit from the antiretroviral therapy (ART), achieving effective viral replication suppression and substantial improvement in life expectancy.¹ Those with an undetectable level of HIV viral load attributed to ART cannot transmit HIV sexually, a concept known as “U=U”.^{2,3} This principle is a cornerstone of the broader “treatment as prevention” strategy⁴ and plays a fundamental role in efforts to end the HIV epidemic.⁵

Globally, U=U perception, namely knowledge, attitude and acceptance of U=U,⁶ shows substantial variations, with 42.3% accurate knowledge in the US but low levels in many Asian countries.^{7,8} In China, studies mainly focus on men who have sex with men (MSM) living with HIV and reveal low level of accurate knowledge of U=U (20%).⁹ Regarding attitude toward U=U, current research indicates that PLWH generally hold moderate levels. An Australian online survey (2012)¹⁰ reported that about 50% of PLWH considered U=U accurate. Meanwhile, a 2017–2018 US survey of over 100,000 sexual minority men found 51% of HIV-positive male participants rated U=U as fully accurate.¹¹ For U=U acceptance, we found relatively low acceptance of U=U among PLWH. Among PLWH in Australia, only 48.2% were confident in U = U as an effective HIV transmission prevention strategy across sexual situations.¹²

A growing body of evidence highlights the potential benefits of U=U perception for PLWH.⁶ Prior studies demonstrate that accurate U=U perception is associated with improved treatment outcomes, including enhanced ART adherence,⁶ viral suppression,¹³ and improvements in CD4 counts and overall physical health.¹⁴ Importantly, U=U perception extends beyond physical health benefits. Research indicates its significant role in reducing HIV-related stigma (ie social HIV-related and self-stigma)^{15–17} and improving psychological well-being.¹⁸ While some studies note behavioral changes associated with increased U=U perception,^{11,19,20} these findings underscore the need for context-specific understanding of how U=U knowledge translates into benefits for PLWH.

Given U=U’s potential benefits in both physical and psychological health among PLWH, a deep understanding of U=U perception among PLWH will facilitate the accordingly strategies to advocate U=U, which is not only significant for “End AIDS” by 2030 but also enhances the health status of PLWH.¹ However, the benefits as demonstrated in the literature, predominantly derived from various contexts, highlights the urgent need to investigate how U=U perceptions may benefit PLWH in China, where cultural and healthcare system differences may shape both the understanding and impact of this crucial message. In China, family lineage continuation and moral standards significantly contribute to the stigma faced by PLWH, as they are often perceived as failing to fulfill societal expectations due to HIV’s association with stigmatized behaviors.²¹ This stigma hinders PLWH’s acceptance of the “U=U” concept and fosters skepticism toward its validity.²² Additionally, healthcare providers may be hesitant to promote the U=U concept because of many factors, including concerns that “zero-risk” claims and fears of being stigmatized as promoting high-risk behaviors.²³ This may also attribute to the fact that some healthcare providers have limited awareness of U=U.²⁴ All these concerns influence whether healthcare professionals endorse and how they communicate with PLWH about U=U, which further hindering how PLWH benefits from U=U.²⁵

Therefore, we conducted an exploratory survey among PLWH, mainly to clarify the status of PLWH’s perception of U=U (including knowledge, attitude, and acceptance) and the relationship with their sexual behaviors and potential physical and psychological benefits (satisfaction of health, depression, self-stigma, quality of life, ART adherence, viral load and CD4+ cell level).

Materials and Methods

Settings and Participants

We conducted a cross-sectional study among PLWH from October 2021 to January 2022. The participants were recruited from the HIV clinic of the Affiliated Changsha Hospital of Xiangya School of Medicine, Central South University, which is a designated hospital for HIV care and provides service for PLWH from all regions in Hunan Province. The trained research assistants recruited participants from the HIV clinic, outlining the purpose of our study and relevant information for participants. The participants were: 1) at least 18 years of age, 2) diagnosed with HIV, and 3) without a history of brain injury, nervous system diseases, or other severe psychosocial disorders. Those who could not communicate or had visual or hearing impairments were ineligible for the study.

A total of 778 individuals participated in this study. We excluded 48 participants with missing responses on over 15% of the questionnaire items pertaining to the perception of U=U, resulting in a final sample of 730 participants. Using Power Analysis and Sample Size (PASS) version 15, with this sample size, we achieved a statistical power of 85.99% to detect a significant difference of 5%, and we utilized a one-sided exact test at a significance level of 0.05, in a population of 56,850.²⁶ These results assume that the population proportion is 50% based on previous studies.⁹

Ethics

This study received ethical approval from the Institutional Review Board of Central South University (E2021134). This study complied with the current version of the Declaration of Helsinki. The research assistants underwent comprehensive training to collect sensitive and private data, ensuring strict confidentiality of participants. We upheld participants' right to informed consent and permitted withdrawal at any time. No identifying information was collected, and all data were exclusively for research purposes, accessible only to authorized researchers.

Data Collection

The recruitment process was carried out by five trained research assistants. Participant recruitment took place in outpatient clinics following approval from the research site. At the clinic, research assistants approached potential participants and introduced the study. Individuals who expressed interest were escorted to a private room, where informed consent was obtained. After providing consent, participants independently completed a structured, paper-based questionnaire. A research assistant remained available throughout to provide clarification or guidance as needed. Completion of the questionnaire typically required 5–10 minutes. Upon completion, each participant received an incentive of 20 RMB. The process was entirely anonymous, with no personally identifiable information collected. For clinical data, participants referred to their own electronic medical records, accessed via their personal mobile phones, to answer relevant questions. Prior to the main survey, we consulted field experts and conducted a pilot test of the questionnaire with a small group of participants.

Measures

We adopted a battery of questionnaires to collect data regarding sociodemographic and clinical characteristics, awareness of U=U, U=U perception, sexual risk behaviors and potential physical health and psychological benefits of U=U (including self-stigma, depression, quality of life, ART adherence, CD4+ cell level, and viral load).

Sociodemographic and Clinical Characteristics

The sociodemographic characteristics were collected based on self-report, namely ethnicity, residence, gender, education level, religious belief, marital status, employment status, sexual orientation, and alcohol and drug use. The clinical characteristics were based on medical record, including the initiation of ART, the coexisting of other sexually transmitted infections, CD4+ cell counts and HIV viral load.

U=U Awareness

We measured U=U awareness by asking a single yes/no question: "Have you heard of the concept of U=U?". U=U perception was operational through the assessment of knowledge, attitude, and acceptability of U=U.

U=U Perception

U=U knowledge was gauged using a 3-item scale as follows:^{27,28} (1) A person living with HIV who is undergoing HIV treatment is unlikely to transmit the virus; (2) A person with an undetectable viral load cannot pass on HIV; (3) If every person living with HIV were on treatment, the HIV epidemic could be ended. After reading each item, the participants indicated their level of agreement with the statement from 1 (strongly disagree) to 5 (strongly agree). A higher average score indicated a participant was more agree with the U=U.

U=U attitude was evaluated using three items grounded in existing researches:^{29,30} (1) transmission risk perception during unprotected anal intercourse with an ART-treated partner living with HIV and with undetectable viral load, (2)

reduction of HIV transmission fear due to awareness of U=U, and (3) relief felt upon recognizing U=U. Each item was scored on the same scale as knowledge (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree), with higher mean scores indicating a more positive attitude.

U=U acceptance measured as confidence in employing U=U as an effective HIV prevention strategy during sexual activity ranged from 1 (not confident at all) to 5 (very confident). The item was “If my viral load remains undetectable, I believe I will not transmit HIV to my sex partner even without using any protection”.

For the three dimensions of U=U perception, a cut-off-point of 4 shows that respondents have accurate knowledge of, totally agree with, or accept U=U as an HIV prevention strategy.

Sexual Risk Behaviors

Sexual risk behaviors were defined as engaging in either unprotected sex or with multiple sexual partners in the last 6 months. The frequency of unprotected sex was assessed using a single question: “How often have you used condoms in the last 6 months?” Participants responded on a 5-point Likert scale ranging from “always” to “never.” “Always” indicated consistent condom use, while other responses implied instances of unprotected sex. The count of sexual partners was based on participants’ self-reported data. Individuals who reported having two or more sexual partners were classified as having multiple partners.

Potential Physical and Psychological Benefits of U=U

Depression severity was evaluated using the Patient Health Questionnaire-9 (PHQ-9),³¹ a well-established and reliable scale for participants to rate how often they have experienced the symptoms described in each item. This 9-item instrument (for example, loss of energy) employs a 4-point Likert scale (0 = not at all; 1 = several days; 2 = more than a week; 3 = nearly every day), resulting in a total score ranging from 0 to 27. A higher total score indicates a higher level of depression.

Self-stigma was assessed by the adapted version of HIV stigma scale from Berger.³² It incorporates 10 items (for example, I am hurt by people’s reactions to finding out I am infected HIV) and each is rated with 4-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree). The higher total score indicates more stigmatization.

Quality of life and health satisfaction were measured to indicate quality of life, with the 2 general items from the brief version of World Health Organization Quality of Life Assessment for HIV/AIDS (WHOQOL-HIV)³³—“How would you rate your quality of life” and “How satisfied are you with your health”. Each item was rated with a 5-point Likert scale (ie, 1 = very dissatisfied; 2 = dissatisfied; 3 = neutral; 4 = satisfied; 5 = very satisfied), with a higher score showing better quality of life.

ART adherence was assessed with the Combined Antiretroviral Therapy Adherence Scale (CASE).³⁴ This scale includes 3 items, namely self-reported adherence, dosing frequency, and the presence of missed doses. The total score of CASE is from 3 to 16, with a higher score indicating better adherence.

Data Analysis

All data were double checked and entered into Epidata3.1, and data analyzed was conducted with SPSS 26.0. Regarding the missing data, we utilized the Multiple Imputation technique, implementing an automatic imputation approach with five iterations. Each dataset was analyzed independently, and the results were subsequently combined to provide a final estimate.

For descriptive statistics, means (Standard deviations, SD; or standard error, SE) and median (quartiles) were used to describe continuous variables. For categorical variables, frequency (percentage) was used to describe the distribution of each variable.

To explore the relationship between U=U perception and risk sexual behaviors, ART adherence, CD4+ cell levels, HIV viral load, depression, self-stigma, and quality of life, the appropriate regression models were chosen based on the distribution of the response variables. In detail, for categorical outcome variable, multiple logistic regression was adopted for the CD4+ cells and HIV viral load level; for count outcome variable, generalized linear model (GLM) with Poisson regressor was used for sexual risk behaviors; and since all the other response variables were skewed, GLM with Gamma

regressor was used. After, we built multivariable models adjusted for potential confounders to explore the stability of their relationship. The details about potential confounders were showed in the appendix file ([Table A](#)). This table included all potential confounders of sexual risk behaviors and associated potential physical and psychological benefits, which were controlled for in the analysis. We used bivariate analysis to pinpoint the Sociodemographic and clinical characteristics linked to risk sexual behaviors and potential physical and psychological benefits, namely the confounding variables. Finally, if the explored relationship was significant in the regression model, we calculated the trend value of p to explore the linear trend change.

Results

Sociodemographic and Clinical Characteristics

The mean age of the participants was 33.6 years (SD = 10.8). Of the 730 individuals, 51% resided in a town or city. The participants were predominantly male (95.1%), and nearly three-fifths were single. About 48.5% were identified as MSM or WSW, and nearly half had attained a bachelor's degree or higher education (45.6%). The median of HIV diagnosis duration was 51 months, with 25% quartile equaling 24 and 75% quartile being 81 ($P_{25}=24$, $P_{75}=81$), ranging from 0.5 to 224 months. The vast majority did not have other sexually transmitted diseases (84.1%) and had initiated ART (97%). Additionally, 527 participants' viral loads (72.2%) were below the detectable level, and more than half of the participants' CD4 counts (54%) were less than 500 cells per microliter. Approximately four-fifths (78.4%) of the participants were employed. Furthermore, only 1.2% of the participants used drugs, and 57% consumed alcohol.

U=U Awareness

Among the 730 participants, 697 provided their options and 63.8% ($n=466$) of them heard U=U before. As showed in [Table 1](#), awareness of U=U was associated with age, ethnicity, gender, education level, marital status, employment status,

Table 1 Sociodemographic and Clinical Characteristics

	Full Sample (Mean±SD/n,%)	Awareness (n,%)	U=U Knowledge (Median, IQR)	U=U Attitude (Median, IQR)	U=U Acceptance (Median, IQR)
Age, years	33.6±10.80	466(63.8%)*	3.0(2.3,3.5)	4.0(3.0,4.5)*	2.0(2.0,3.0)
Ethnicity					
Han	677(92.7)	427(65.9)*	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Other	53(7.3)	39(79.6)	3.0(2.3,3.5)	4.0(3.3,5.0)	2.0(2.0,3.0)
Gender					
Male	694(95.1)	455(68.8)*	3.0(2.3,3.5)	4.0(3.3,5.0)*	2.0(2.0,3.0)
Female	36(4.9)	11(30.6)	2.8(2.0,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Education					
Less than middle school	68(9.3)	21(32.3)*	2.8(2.0,3.3)*	3.0(2.5,4.0)*	2.0(2.0,3.0)
Middle school	84(11.5)	43(53.1)	2.8(2.0,3.2)	3.5(2.5,4.0)	2.0(2.0,3.0)
High school	38(5.2)	19(51.4)	2.9(2.2,3.5)	3.0(2.5,4.0)	2.0(2.0,3.0)
Technical secondary school or junior college	207(28.4)	139(62.2)	3.0(2.3,3.3)	4.0(3.0,4.5)	2.0(2.0,3.0)
Bachelor or above	333(45.6)	244(78.0)	3.0(2.5,3.5)	4.0(3.5,5.0)	2.0(2.0,3.0)
Religion belief					
No	664(91.0)	419(66.2)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Yes	66(9.0)	47(73.4)	2.5(2.0,3.3)	4.0(3.0,5.0)	2.0(2.0,3.0)
Marital status					
Married/Partnered	248(34.0)	149(63.1)*	2.9(2.3,3.5)	4.0(3.0,4.0)*	2.0(2.0,3.0)
Divorced/Widow/Separated	73(10.0)	40(55.6)	2.8(2.3,3.3)	3.5(3.0,4.0)	2.0(2.0,3.0)
Single	409(56.0)	277(71.2)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Employment status					
No	158(21.6)	81(53.6)*	2.8(2.0,3.5)	3.5(3.0,4.0)*	2.0(2.0,3.0)
Yes	572(78.4)	385(70.5)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)

(Continued)

Table 1 (Continued).

	Full Sample (Mean±SD/n,%)	Awareness (n,%)	U=U Knowledge (Median, IQR)	U=U Attitude (Median, IQR)	U=U Acceptance (Median, IQR)
Sexual orientation					
Heterosexuality	206(28.2)	102(50.5)*	2.8(2.3,3.3)	3.5(3.0,4.0)*	2.0(2.0,3.0)
MSM/WSW	354(48.5)	249(74.6)	3.0(2.3,3.5)	4.0(3.0,5.0)	2.0(2.0,3.0)
Bisexuality	100(13.7)	71(74.7)	3.0(2.5,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Unsure	70(9.6)	44(66.7)	3.0(2.5,3.5)	3.5(3.0,4.0)	2.0(2.0,3.0)
Alcohol					
No	313(42.9)	198(65.1)	3.0(2.3,3.5)	4.0(3.0,4.0)*	2.0(2.0,3.0)
Yes	417(57.1)	265(67.9)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Drugs					
No	9(1.2)	2(66.7)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Yes	721(98.8)	462(67.1)	3.0(2.6,3.5)	3.5(3.0,4.0)	2.0(2.0,3.5)
Other STIs					
No	614(84.1)	399(67.9)	3.0(2.3,3.5)*	4.0(3.0,4.5)	2.0(2.0,3.0)*
Yes	116(15.9)	67(61.5)	2.8(2.0,3.3)	4.0(3.0,4.5)	2.0(1.0,3.0)
ART initiation					
No	22(3.0)	10(47.6)	2.3(2.0,3.3)*	3.0(3.0,4.0)*	2.0(1.0,2.0)
Yes	708(97.0)	455(67.5)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Viral load					
Under detective level	527(72.2)	362(71.1)	3.0(2.5,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
More than 20 copies	81(11.1)	51(65.4)	2.8(2.0,3.3)	4.0(3.0,4.3)	2.0(2.0,3.0)
Data unavailable	122(16.7)	53(48.2)	2.8(2.0,3.3)	3.8(3.0,4.0)	2.0(2.0,3.0)
CD4					
Less than 500 per μ L	394(54.0)	241(64.8)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
More than 500 per μ L	300(41.1)	202(69.2)	3.0(2.5,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)
Data unavailable	36(4.9)	23(69.7)	2.8(2.0,3.0)	4.0(3.1,5.0)	2.0(1.0,3.0)
Residence					
Rural area	358(49.0)	215(62.5)*	2.8(2.3,3.5)*	4.0(3.0,4.0)*	2.0(2.0,3.0)
Town or City	372(51.0)	251(71.1)	3.0(2.3,3.5)	4.0(3.0,4.5)	2.0(2.0,3.0)

Note: * $p < 0.05$.

Abbreviations: SD = standard deviation; IQR=interquartile range; MSM = men who have sex with men; WSW = women who have sex with women.

sexual orientation and residence. In details, participants perceiving U=U ($M=32.06$, $SE=0.434$) were younger than those who were not informed ($M=37.08$, $SE=0.838$). Post-hoc analysis revealed that individuals with a bachelor's degree or higher were more likely to be aware of U=U compared to those with a middle school education level or below. Similarly, single individuals demonstrated greater awareness of U=U than those who were divorced, widowed, or separated. Furthermore, MSM, WSW or bisexual individuals were found to be more aware of U=U than heterosexual or unspecified individuals.

The Relationship of U=U Knowledge, Attitude and Acceptance

The knowledge of U=U was positively correlated with attitude ($r_s=0.334$, $p<0.001$) and acceptance ($r_s=0.433$, $p<0.001$), as was the association between attitude and acceptance ($r_s=0.225$, $p<0.001$).

U=U Knowledge

In terms of U=U knowledge, the median score was 3.0 ($P_{25}=2.3$, $P_{75}=3.5$), and 13.6% had a mean score ≥ 4 (Figure 1). As in Table 1, the level of U=U knowledge was associated with education, coexisting of other STIs, ART initiation and residence. The findings indicated that, in comparison to individuals holding a bachelor's degree or higher, those with a middle school education [$\beta(95\% \text{ CI})=-0.078(-0.155, -0.001)$] or less [$\beta(95\% \text{ CI})=-0.115(-0.186, -0.044)$], as well

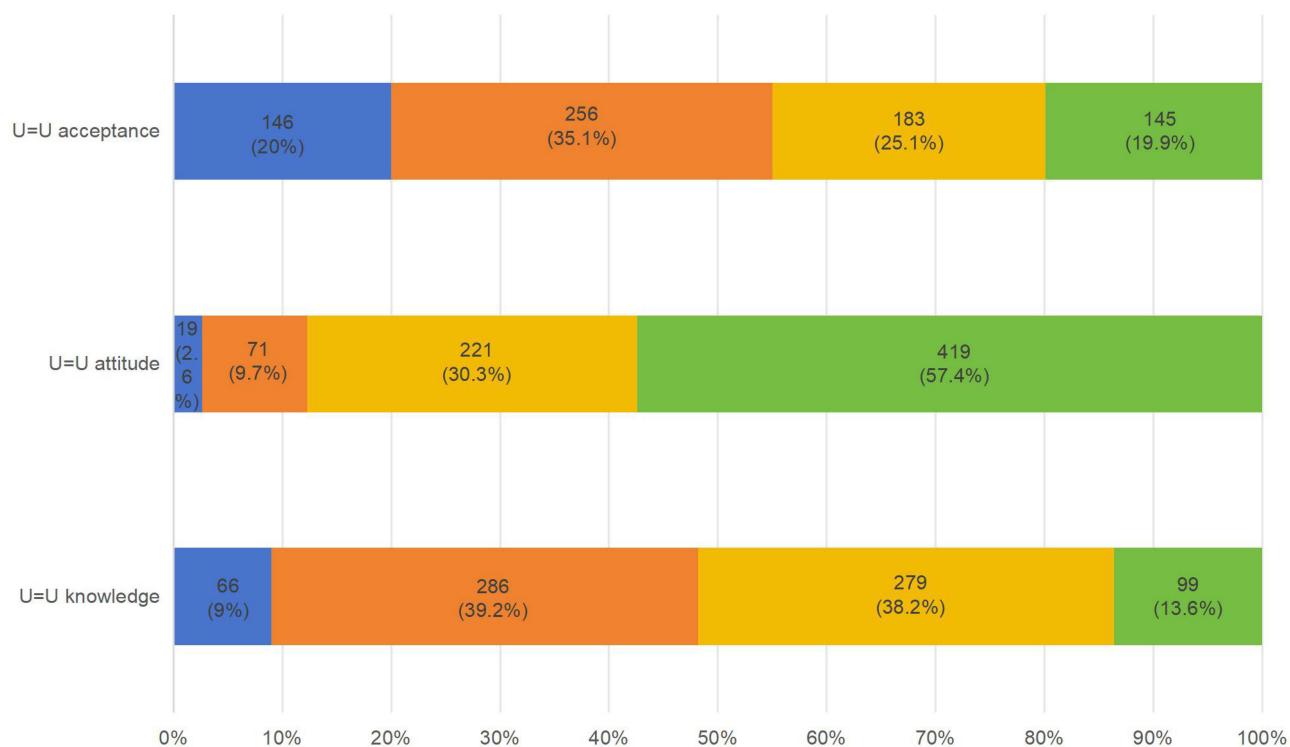


Figure 1 U=U knowledge, U=U attitude and U=U acceptance scores.

Notes: ■ [1, 2) ■ [2, 3) ■ [3, 4) ■ [4, 5]. The blue box indicates a score between 1 and 2, excluding 2. The orange box indicates a score between 2 and 3, excluding 3. The yellow box indicates a score between 3 and 4, excluding 4. The green box indicates a score between 4 and 5.

as those with a technical secondary school or junior college education [β (95% CI)=-0.064(-0.115, -0.013)], tended to have a lesser understanding of U=U.

U=U Attitude

As for U=U attitude, the median was 4.0 ($P_{25}=3.0$, $P_{75}=3.5$) and 57.4% scored ≥ 4 (Figure 1). In the univariate analysis, age, gender, education level, marital status, employment status, sexual orientation, alcohol use, ART initiation and residence were associated with the attitude. The analysis revealed that individuals in the younger age group [β (95% CI)=-0.006(-0.007, -0.004)] were more likely to have a positive attitude towards U=U. In comparison to those holding a bachelor's degree or higher, individuals with the other four levels of education exhibited a more negative attitude towards U=U. Furthermore, when contrasted with single individuals, those in other two categories tended to have a negative attitude; the MSM or WSW scored higher than the heterosexual individuals.

U=U Acceptance

Regarding for U=U acceptance, the median was 2.0 ($P_{25}=2.0$, $P_{75}=3.0$) and 19.9% scored at least 4 or more (Figure 1). The bivariate analysis only indicated those who did not have other STIs (95% CI: 0.048, 0.233) tended to accept U=U as an HIV preventive strategy.

The Association Between U=U Perception and Sexual Risk Behaviors

As showed in Table 2, the results showed acceptance toward U=U was positively associated with more unprotected sex ([β (95% CI)=0.21(0.045,0.365)], with a P value for trend equaling with 0.018. The relationships among other dimensions of U=U perception and risk sexual behaviors were not statistically significant either in the unadjusted or adjusted models.

Table 2 The Association Between U=U Perception and Sexual Risk Behaviors

Sexual Risk Behaviors	U=U Knowledge		U=U Attitude		U=U Acceptance	
	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)
Unprotected sex	0.03(-0.208,0.264)	0.07(-0.053,0.189) ^a	-0.06(-0.266,0.138)	-0.06(-0.257,0.147) ^b	0.21(0.045,0.365)*	NA
Multiple partners	0.07(-0.160,0.304)	NA	-0.02(-0.225,0.177)	-0.08(-0.292,0.129) ^c	0.10(-0.059,0.259)	NA

Note: *p <0.05. U=U means Undetectable = Untransmittable which is the scientific consensus that people living with HIV(PLWH) who maintain an undetectable viral load cannot sexually transmit HIV to others. ^aResidence is controlled in the adjusted model. ^bResidence is controlled in the adjusted model. ^cGender,marital status and sexual orientation are controlled in the adjusted model.

Abbreviation: NA, not applicable.

The Association Between U=U Perception and Potential Physical and Psychological Benefits

As showed in Table 3, we adopted GLM with a Gamma distribution to explore the relationship between U=U perception and perceived quality of life, perceived health satisfaction, depression, self-stigma and ART adherence. Though we detected some significant relationships, they became statistically insignificant in the adjusted model. As for the relationship between U=U knowledge and perceived health satisfaction, it was significant in the unadjusted model but became insignificant when tested for the trend.

The multinomial regression model was used to explore U=U perception’s relationship with HIV viral load and CD4+ cell levels. Compared to participants with an undetectable viral load, PLWH with a detectable or unavailable viral load tended to have less understanding of U=U. Additionally, those with unavailable viral data exhibited a more negative attitude towards U=U. Regarding the CD4+ cell levels, when compared whose cell counts less than 500 copies/mL, PLWH with missing data were more likely to have lower level of knowledge and acceptance of U=U. All the P values for trend of these relationship were less than 0.05.

Table 3 The Association Between U=U Perception and Potential Physical and Psychological Benefits

Variable	U=U Knowledge		U=U Attitude		U=U Acceptance	
	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)	Unadjusted Model (β,95% CI)	Adjusted Model (β,95% CI)
Perceived quality of life	0.02(-0.002,0.040)	0.01(-0.007,0.035) ^a	0.02(0.005,0.040) *	0.01(-0.007,0.029) ^f	0.01(-0.009,0.021)	NA
Perceived satisfaction of health	0.03(0.003,0.046)*	0.02(-0.004,0.039) ^b	0.02(-0.003,0.033)	0.01(-0.006,0.032) ^g	0.001(-0.015,0.017)	-0.002(-0.018,0.013) ^l
Depression	0.007(0.076,0.062)	0.004(-0.067,0.074) ^c	0.02(-0.009,0.054)	0.01(-0.023,0.040) ^h	0.03(-0.016,0.083)	0.04(-0.013,0.087) ^m
Self-stigma	0.003(0.017,0.023)	NA	0.02(0.0,0.034)	NA	-0.002(-0.016,0.013)	NA
ART adherence	0.003(0.019,0.013)	NA	0.002(-0.012,0.015)	0.01(0.000,0.014) ⁱ	-0.01(-0.023,-0.001)*	NA
Viral load						
Under detective level	Ref	Ref ^d	Ref	Ref ^f	Ref	NA
More than 20 copies	0.65(0.485,0.873)**	0.69(0.503,0.903)*	0.95(0.743,1.209)	1.00(0.747,1.356)	0.83(0.674,1.031)	NA
Data unavailable	0.65(0.507,0.873)**	0.68(0.528,0.884)**	0.75(0.617,0.917)**	0.79(0.635,0.977)*	0.90(0.755,1.070)	NA
CD4						
Less than 500 per μL	Ref	Ref ^e	Ref	Ref ^g	Ref	NA
More than 500 per μL	1.15(0.953,1.378)	1.13(0.937,1.357)	1.01(0.935,1.277)	1.01(0.912,1.258)	0.91(0.909,1.180)	NA
Data unavailable	0.62(0.400,0.945)*	0.62(0.395,0.959)*	1.12(0.825,1.170)	1.01(0.763,1.486)	0.67(0.474,0.940)*	NA

Note: *p <0.05; **p <0.01; U=U means Undetectable = Untransmittable which is the scientific consensus that people living with HIV(PLWH) who maintain an undetectable viral load cannot sexually transmit HIV to others; Potential physical and psychological benefits include following indicators: quality of life, depression, self-stigma, ART adherence, viral load and CD4+cell level; ^aEducation is controlled in the adjusted model. ^bOther STIs and ART initiation are controlled in the adjusted model. ^cOther STIs is controlled in the adjusted model. ^dEducation, ART initiation and residence are controlled in the adjusted model. ^eResidence is controlled in the adjusted model. ^fEducation and sexual orientation are controlled in the adjusted model. ^gSexual orientation and ART initiation are controlled in the adjusted model. ^hMarital status, sexual orientation and alcohol are controlled in the adjusted model. ⁱSexual orientation and alcohol are controlled in the adjusted model. ^jResidence,gender,education and ART initiation are controlled in the adjusted model. ^kResidence is controlled in the adjusted model. ^lOther STIs is controlled in the adjusted model. ^mOther STIs is controlled in the adjusted model.

Abbreviation: NA, not applicable.

Discussion

This exploratory survey involving 730 PLWH who were relatively young and highly educated. Regarding perception of U=U, participants demonstrated a moderate level of a positive attitude towards the idea. However, their knowledge and acceptance of U=U as an HIV prevention strategy was relatively low. Besides, the acceptance of U=U was positively related to unprotected sexual behaviors. The knowledge and attitude toward U=U were associated with viral load status and CD4+ cell count levels.

The perception of U=U showed an inconsistent among knowledge, attitude and acceptance, as 57.4% believe in U=U but only 13.6% comprehensively understood U=U and 19.9% accepted treatment as prevention. The acceptance rate of U=U is notably lower than that in the United States (83.9%)¹¹ and that in Australia (87.0%).¹⁹ The level of knowledge is below that recorded in Italy (52%)³⁵ and Brazil (80.4%).³⁶ Likewise, the degree of acceptance is lower than that observed in Australia (87.0%).¹⁹ But our results are similar to those of a study in MSM from Chengdu,³⁷ which might be explained by insufficient promotion and dissemination of U = U information through public channels and various key stakeholders in China, supported by the fact that a significantly smaller number of organizations from China have signed on to share the U=U message compared to those in the settings being compared, as indicated by the U=U global community.³⁸ In addition, studies show healthcare providers often lack awareness and confidence in communicating the U=U message,³⁹ and further they may be reluctant to discuss U=U with their PLWH or may convey ambiguous messages to PLWH.²³ This situation hindered PLWH to comprehensively understand U=U, which in turn negatively impacted their attitude and acceptance.

The findings indicated that PLWH who adopted the U=U prevention strategy reported higher instances of unprotected sex but no change of number of sexual partners, a trend consistent with previous researches.⁴⁰ The primary driver behind this shift appears to be a misconception or misunderstanding of the U=U message, coupled with insufficient understanding of STIs beyond HIV.⁴¹ This underscores the critical need to convey the U=U message accurately, emphasizing that while HIV is not transmittable when viral load is undetectable, this does not apply to other STIs. It highlights the necessity for healthcare providers to communicate clearly with PLWH, ensuring they are aware of the importance of preventing other STIs, which includes the use of condoms, as well as the potential benefits of pre- and post-exposure prophylactic antibiotics and vaccines.

Regarding U=U perception's relationship with potential physical and psychological benefits, we found that they were associated with HIV viral load and CD4+ cell count levels; yet, the results showed no association with quality of life, depression, self-stigma¹⁷ or ART adherence. Consistent with previous result,¹¹ PLWH whose viral load were detectable or unavailable and unavailable CD4+ cell counts were less inclined to less U=U knowledge. Similarly, PLWH with unavailable viral load showed more negative attitude toward U=U. In addition, lower level of U=U acceptance was related to the unavailable CD4 cell counts. The potential reason is the lower engagement in HIV-related care and hinder the contact of U=U message from the clinical settings.²⁰ Besides, some existing evidence indicates PLWH benefit from accurate U=U perception⁴¹ as they perceive less self-stigma⁴² and depression,⁴³ and better ART adherence⁴ and even quality of life;⁴³ yet, our results did not detect any significant relationships. Both the partial understanding and the varied reactions of PLWH to the potential consequences of U=U may contribute to this difference. PLWH who have heard of U=U do not totally have a comprehension of U=U, such as how to reach the first U (undetectable) and whether negligible risk indicates zero risk;^{6,44} some PLWH believe in U=U, but as the HIV viral load undetectable status may change, and they are still concerned about HIV sexually transmission.^{44,45}

Our study provides initial insight regarding whether and how PLWH benefit from U=U in China. Further endeavors are warranted to advocate for U=U among this population, given their inadequate knowledge and misconceptions. These misconceptions hinder their acceptance of U=U as an HIV prevention strategy, thereby preventing them from experiencing its benefits, including reductions in self-stigma, improvements in ART adherence, alleviation of depression, and enhancements to quality of life. To ensure accurate understanding of U=U is the most crucial prerequisite for harnessing the benefits of treatment as prevention. Specifically, the first "U" emphasizes the importance of ART adherence and maintaining a sustainably undetectable viral load. The second "U" signifies zero risk of HIV transmission sexually. Additionally, PLWH should be thoroughly informed about the social and personal benefits of U=U. But special attention should be paid to the risk of other STIs, and PLWH should be informed the importance of prevention strategies of other STIs even reaching U=U. Based on our results and previous study,⁴⁶ PLWH may benefit more from U=U if healthcare providers deliver simple, clear, and consistent messaging about U=U, and integrate it with other HIV and STIs prevention

information, and in a patient-centered approach, focusing primarily on achieving viral suppression and emphasizing that U=U remains safe only while adhering to ART. Besides, whether PLWH immune function indicators (HIV viral load and CD4+ cell counts) are associated with their U=U perception need further explorations in a longitudinal study.

Limitations

Our study was subject to certain limitations. As it was a cross-sectional study, we cannot establish a causal relationship between the perception of U=U and health indicators/sexual behaviors; this should be further investigated in future longitudinal studies. Additionally, the sample was drawn from the central region of China and predominantly consisted of males and younger individuals, which restricts the generalizability of our findings to other demographic groups. Lastly, due to economic constraints, the data on HIV viral load and CD4+ cell counts were sourced from medical records rather than laboratory tests. This may have contributed to the inconsistency in conclusions regarding the relationship between U=U perception and immune function indicators.

Conclusions

Among the 730 participants, with a mean age of 33.6 years (SD = 10.8), the majority were male (95.1%), had initiated ART (97%), nearly half held a bachelor's degree or higher (45.6%) and identified as homosexual (48.5%), and 63.8% were aware of U=U. There is inconsistency existing among PLWH's knowledge, attitude and acceptance of U=U: 57.4% perceived U=U accurate, yet only 13.6% had a comprehensive grasp of the concept, and 19.9% accepted U=U as a strategy for HIV prevention. Notably, PLWH have not been fully benefiting for U=U. The acceptance of U=U among PLWH has been positively correlated with an increase in unprotected sexual behaviors. U=U knowledge and attitude regarding U=U were found to be associated with the viral load. CD4+ cell counts were found to be related to U=U knowledge and acceptance. To ensure that PLWH can fully benefit from the U=U campaign, it is essential to disseminate clear and accurate information about U=U, as well as the personal and social benefits. Additionally, while promoting the U=U message, it is crucial to pay special attention to ensure that PLWH are thoroughly informed about the significance of preventing other STIs.

Abbreviations

U=U, Undetectable = Untransmittable; PLWH, People living with HIV/AIDS; HIV, Human immunodeficiency virus; AIDS, Acquired immunodeficiency syndrome; ART, Antiretroviral therapy; MSM, Men who have sex with men; SD, Standard deviations; SE, Standard error; GLM, Generalized linear model; WSW, Women who have sex with Women; 95% CI, 95% confidence interval; STIs, Sexually Transmitted Infections; PASS, Power Analysis and Sample Size.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Statement

This study received ethical approval from the Institutional Review Board of Central South University (E2021134). This study complied with the current version of the Declaration of Helsinki.

Informed Consent Statement

The study had upheld participants' right to informed consent.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors have no conflicts of interest to disclose for this work.

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