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Perceived Access to Water: Associations with Health in Rural Uganda

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Abstract Water security has been associated with myriad health concerns. However, measures of access to water vary and may not reflect reality or user priorities, affecting our understanding of the effect of water security on health. This study aimed to: 1) examine relationships between established measures and perceived access to water; and 2) compare the ability of established measures versus a perceived measure to predict health outcomes. Data collection included baseline anthropometrics, bi-monthly morbidity histories, and a final survey over a four-month period among 100 households in Uganda's rural, semi-arid savannah. Hierarchical regression models were fitted to test relationships. Despite low water security, 68% of participants did not report illness. Perceptions of better access was significantly associated with fewer minutes walking to source and, surprisingly, with fewer litres collected yesterday/person. Perceived better access (β=-0.09, $p<0.10$) and more public ownership (β =-0.09, $p<0.10$) were associated with lower percentage time ill. Both effects were small. Understanding of the drivers of perceived water access may provide useful insights into social dimensions of water security, which may influence health.

Keywords: *water security, health, perceived access, uganda, water quantity*

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1. Introduction

The United Nations has defined water security as, "sustainable access to adequate quantities of acceptable quality water…" [1]. This definition includes three inter-related and important dimensions of access, all of which have been associated with increased diarrheal, skin and respiratory infections – water quality, water quantity, and reliability/sustainability [2,3,4,5,6]. To date, measurement of access to water has varied from study to study and has also evolved within monitoring institutions. Typically, measures of access to water include aspects of locational access (proximity or distance), time (to fetch water, waiting times), financial access (cost of water), microbiological and chemical quality or whether a source is 'improved' versus 'unimproved', and reliability (particularly for surface water sources).

The designation of access as 'improved' or 'unimproved' is used as an indicator of water quality [7] and has been used to monitor progress towards the Millennium Development Goals. The WHO/UNICEF Joint Monitoring Program now promotes more clear definitions of access which incorporate type of source (surface water versus piped) and location of source/tap (in dwelling or on a plot). Specifically, the categories of access are: (a) drinking water directly collected from surface water (eg, ponds), or 'unimproved' water sources; (b) 'improved' sources other than piped household connections; and (c) 'improved' household connections in a dwelling, plot or yard [8].

Research in Chile has defined access to water using a combination of tap/source location (on private lot/within residence), distance (< 1km from home), adequacy (average of 20 litres per person/day) and ownership to form categories for access. Also in Chile, financial access has been measured as per capita expenditure on drinking water and as a percentage of total expenditures [9]. Health studies have often used proximity or distance, finding that increased distance to the nearest water source associated with poorer health, including higher trachoma prevalence in Tanzania [10]. In a systematic review of distance to water and health, Wang and Hunter [5] concluded that distance to water source may be an important risk factor for diarrheal diseases in children. In a similar vein, volume of water used by a household has been associated with health [11] and depends greatly on accessibility as determined primarily by distance and time, but also including reliability and potentially cost [2]. In this way, quantity may be measured directly (litres collected) or measured indirectly as distance or time to collect water. Reliability is inherently related to quantity, but can be captured as inaccessibility due both water source-related issues (eg, a broken pump handle or evaporation of surface sources) or social conflicts with source owners or managers, etc. Health concerns may be high when water collected falls below 5 litres per person/day, distance exceeds 1km or collection time exceeds 30 minutes [2].

With varying measures and the combination of aspects of access within one measure, it can be difficult to compare across studies or to clearly reflect unique challenges to water security found in different settings.

While established measures of access are useful for monitoring of progress towards development goals over time, these measures are unable to reflect the differing priorities of users, or the eco-social processes which may influence access and the relationship between access and health [12]. For example, a user may better balance dimensions of access and prioritise based on their own needs and experiences. Different users may prioritise differently. In addition, agency, gender, relationships and power may be social structures which support or hinder access for some members. In this way, perceived access to water may reveal complex or dynamic interplay between social structures which influence access to resources. For example, in Uganda, ethnic privilege and political favouritism has shaped the infrastructural access to water and land over the past 40 years [13]. Research in India has shown that the exercise of agency involves interdependence, whereby marginalised groups gain access to water through social arrangements with more privileged members [14]. This was echoed in findings from Uganda, where water sharing and reciprocity appeared to be crucial between wealthy and poor households [15]. Likewise in Nepal, family networks have been identified as an important dimension of agency to access water [16].

Perceived level of access also includes a dimension of relative comparison, whereby some users may rate their access lower if others are perceived to have better access. These assessments of relative level of access may highlight areas of social stratification which influence access. In settings where access would bluntly be classed as ‘poor’ using international definitions, the use of perceived level of access may allow for differentiation within the community, either through different perceptions of risk, different priorities, different uses and needs for household water, different weighting of aspects of access, social structure and agency, or relative comparison with other community members. What is not understood is whether there is a close relationship between the established measures of water security and perceived access to household water. Understanding the perceived access may allow for a better understanding of which measures of access drive the perception and reveal social structures which hinder or facilitate access. The focus of this study was to compare two established dimensions of water security (ie, quantity and reliability) with perceived level of access and estimate relationships between these indicators of water security and health.

To our knowledge, no studies have evaluated the association between perceived level of access to household water and health. One study compared perceived access to established measures and found that self-reported time to collect water was significantly associated with perceived level [17]. This study was limited in its unclear sampling of individuals within communities and its use of three categories for perceived access – ‘readily available’, ‘not easily available’, and ‘problematic’ – rather than ordinal ranks. Useful insights may be gleaned from health studies in other realms which compare perceived and objective water security and health. For example, perceived level of access to recreational facilities has been associated with increased physical activity among youth in the USA, while most objective measures did not [18]. Likewise, objectively measured distance to a supermarket was not associated while perceived supermarket access was strongly associated with increased fruit and vegetable intake among low-income residents in Boston [19]. These studies highlight that the interactions between people and their environments are more complex and dynamic than can be captured by proximity measures alone.

Using morbidity histories and surveys conducted over a four-month period spanning both wet and dry months (mid-Jan to mid-May), in three communities in south-western Uganda, this study: 1) examined the relationship between established dimensions of water security (quantity and reliability) and perceived level of access; and 2) compared the ability of established measures of water security versus a perceived measure to predict percentage self-reported time spent ill.

2. Methods

2.1. Study Site and Sampling

The semi-arid savannah serves as a useful location for understanding the relationship between water access, as this region involves an annual extended dry season (June-September), yet high rainfall during the wet season (mean: 1000mm) [20]. In addition to this physical environment, the general lack of widespread government provision of ‘improved’ groundwater sources (eg, boreholes) and/or maintenance of drinking water sources means that water access is generally poor in this region in Uganda, located within Kiruhura District. Here, Bahima pastoralists and Bairu cultivators together form the Banyankole people and constitute 92% of the population [21].

This study was conducted in three villages in Kiruhura District, which encompasses 4104 km^2 [20] (see Figure 1). The sampling for this study first involved purposeful selection of the three sub-counties in Kiruhura District, which largely rely on surface water for domestic purposes. Next, within those subcounties, one village was randomly selected from each sub-county, using a random number generator (Microsoft Excel Basic 2003, Redmond, WA). The study sample was then drawn from all the households in these three villages. Households were selected by simple random sampling from village rosters, using proportional population sampling from the total households from the three villages. Within the study area, there are two ‘improved’ sources with communal access and only one permanent surface water source is accessible to households living near it – Lake Kakyera [22]. Most households in the region rely on hollowed out ‘farm ponds’ on private property which fill with rain. These small surface water sources are prone to both evaporation and to contamination. While this study did not directly measure water quality, farm ponds in the study area have been shown to contain *E. coli*, *Citrobacter*, *Enterobacter*, *Proteus*, *Salmonella*, and *Yersinia* species [23]. In that work, mean presumptive *E. coli* bacterial counts were 26.63 CFUs/1 mℓ for farm ponds, 3.5 CFUs/1 mℓ for large surface sources and 0.13 CFUs/1 mℓ for boreholes, thus international drinking water standards were not met on average for any water source type.

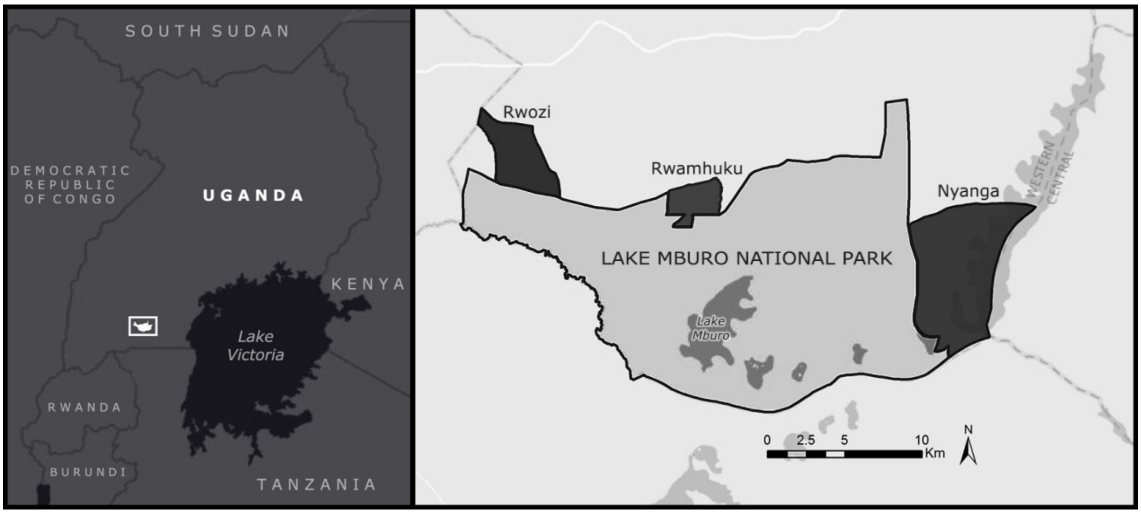

Figure 1. Map of study area: Villages of Rwozi, Rwamuhuku, and Nyanga

A power calculation was performed to ensure statistical ability to detect significant differences in morbidity between those with high levels of access to water (defined in several ways, outlined below) and those with low levels of access. We expected there to be a 15% prevalence of infectious diseases symptoms (eg, diarrhea) in those with high access and 30% in those with low access, with a standard deviation of 25. To have 80% power for detecting the difference between exposure groups at a 95% confidence level, we needed a total of 96 households [24]. Thus, we sampled 100 households, and each member was then enrolled (n = 538).

2.2. Health Data

Morbidity histories are important tools for assessing health by providing direct measures of symptoms [25]. There is broad scientific consensus that recall of non-life-threatening illness becomes unreliable after two weeks [26]. Each enrolled household participated in morbidity histories, conducted in *Runyankole* by two health workers every two weeks for four months, with varying rainfall (February-May 2009). Health questions were asked to an adult household member (15yr+), typically an adult female. If no adult was present, a repeat visit was scheduled during the two-week period, with a maximum of three repeat visits. After the third attempt, results for that household and time period were considered missing.

Self-reported disease symptoms and duration were reported for each household member who was ill during the preceding two weeks, with emphasis on infectious disease symptoms, using those listed by the World Health Organization [27] and from research in pastoralist communities [28], including different types of diarrhea, cramping, nausea, vomiting, rash, lesions, cough, neck stiffness, seizures, altered consciousness, muscle weakness, jaundice, fever, chest pain, and loss of appetite. Mbarara University faculty, medical students, and field assistants were consulted on translation of symptoms into readily recognized terms in *Runyankole*. Illness was defined as experiencing one or more of those symptoms. Diarrhea and vomiting in Uganda are prevalent in every season and highest during the wet seasons [29]; malaria is not markedly seasonal in the area [30].

All self-reported symptoms were compiled and days spent ill were summed from the morbidity histories to generate a percentage self-reported time spent ill over the four months of observation for each participant, where the numerator was the days spent ill and the denominator was the number of days observed (accounting for missing data such as days spent outside of the household, etc.).

2.3. Measures of Perceived Access and Water Security – Quantity and Reliability

To address the first research aim, during the final morbidity history visit, we conducted a survey. This survey included questions related to perceived access to water and variables related to water security. Specifically, to capture dimensions of water quantity, we measured litres collected per person, minutes spent walking to source, and distance to source. Distance from the home to the water source was calculated using a GPS unit. For reliability, we measured ownership, seasonality of source and inaccessibility for any reason in the past two weeks. Each measure is detailed below.

We recorded perceived level of access (using a Likert-type score), where better access = 3 and poor access = 1. In the survey, several questions were asked that required the respondent to compare the own household's situation to others in the community. The question related to perceived water access was, "What is your level of access to water for home use compared to your neighbours?" For all similar questions, respondents were given the options 'very high/high', 'average', or 'low/very low'. These responses were then assigned values from 3 (very high) to 1 (very low). These options were similar to other studies measuring perceived access to features. For example, one study about perceived access to community amenities used the question "How well-placed do you think your home is for _____?" [31]. The following options were given: 'very well-placed', 'fairly well-placed', 'not very well-placed', or 'not at all well-placed'.

Self-reported litres of water collected yesterday was reported as the number and size of jerry cans filled yesterday and then calculated in litres per person using household size. Minutes spent walking one way to water source, waiting in queue and returning was asked to respondents. Responses were recorded into one of the following ordinal values (4 = <10 minutes, 3 = 11-29 minutes, 2 = 30-45 minutes, 1 = 46+ minutes). Water source ownership was treated as an ordinal variable where more public sources were assigned high values (4 = public source), followed somewhat public (3 = shared), personal source (2) and privately owned by boss (1). Inaccessibility within the past two weeks was recorded as a binary variable. Seasonality of water source (source evaporates during the dry season or not) was also compiled as a binary variable. GPS coordinates were obtained for each household location, along with those for each of the named water sources (collected in the survey). These coordinates were used in a Geographic Information System to measure Euclidean distance from each house location to the specified household water source (in kilometres). Spatial techniques were conducted using ArcMap 10.2 (ESRI, Redlands, CA).

2.4. Demographic and Potential Confounder Data

During the survey, additional demographic data were captured for individuals and households including age, ethnicity, sex, sex of acting head of household, and length of time living in the community, household size, and self-reported wealth status (Likert-type scale of high to low). In addition, health-behaviour data were collected including water treatment method, type of toilet facility and observed hygiene behaviours.

Age and wealth may serve as potential confounders in the relationship between access to water and percentage time spent ill [32]. In addition, the lack of water treatment and the type of toilet facility may influence illness [4], outside of level of access to water.

Hygiene behaviours could also be considered either a potential confounder or may be in the causal pathway in the relationship between water access and health. For example, a household may struggle to maintain hygienic conditions without access to water and thus may suffer from increased infections. Alternatively, even if a household has relatively good access to water, if hygienic conditions are not maintained, there may be higher levels of infection. Therefore, a set of household hygiene indicators were chosen from those compiled by USAID [33]. Spot observations (binary data) were made while conducting the survey to record: availability of soap, presence of a latrine, presence of faeces in the home, cleanliness of utensils, and proper storage of water. These indicators have been associated with health in other studies [32]. A hygiene score was calculated for each household by summing the positive hygiene indicators, where higher values indicate more hygienic households (range 0 to 10).

Malnutrition has also been associated with increased susceptibility to infections [34]. Therefore, anthropometric measurements were collected at enrolment. For participants aged 3 and older, this included Body Mass Index (BMI) and Triceps Skin Fold Thickness (TSFT). For children under 3 years old, recumbent height and weight were obtained. TSFT measurements were taken in millimetres using SlimguideR calipers (Creative Health Products, Plymouth, MI) and were taken in triplicate, then averaged. Weight was measured in kilograms using a SecaR (Seca, France) scale. Height was measured in inches using a StarrettR (Germany) measuring tape, and was later converted to centimetres for BMI calculations. Shoes and heavy clothing were removed during weight/height measurement.

Z-scores were calculated using Stata v13 software (College Station, TX) for weight-for-age (WAZ) and height-for-age (HAZ), using an international reference population for vulnerable groups (WHO 1983) used in other research in Uganda [35]. Median and standard deviations in the reference population for each age were averaged between males and females. Then, a binary malnutrition variable was generated for each participant using the following criteria. For those under 3 years old, a WAZ or HAZ < -2 were considered malnourished. For participants 3-20 years, a TSFT < 4 mm or BMI < 15 (approximately the 35th percentile BMI for a 3-year-old in the USA) was categorized as malnourished. For participants over 20 years, BMI < 18.6 was categorized as malnourished [36].

For descriptive purposes, rainfall data were obtained from the Nshara rangers' station at Lake Mburo National Park, where records are kept for total monthly rainfall, using a rain gauge on site.

2.5. Statistical Analyses

To address the first research aim, we fitted separate linear regression models, using the household-level data, to test which established measures of water security related to quantity and reliability were associated with perceived access. Specifically, each model included perceived level of access as the dependent variable of interest and, separately, models included the following independent variables: litres collected yesterday/person, distance from home to water source, minutes spent walking to source, ownership, whether the source was inaccessible at any time during the past two weeks, and seasonality of source. Results are reported as standardised β coefficients, with relevant 95%CIs and p-values.

To answer the second research aim, we first explored the inclusion of interaction terms in regression models. We determined that Wealth*Age and Sex*Age were significant predictors of percentage time ill. Initially, water treatment was intended to be included in the models as an independent variable. However, after descriptive analyses, we found that 95% of households reported treating drinking water (yet this was never observed during household visits). Due to the lack of variation and the unreliability, this variable was not included in regression analyses. Thus, we fitted hierarchical linear regression models to compare the ability of six established measures of water security versus perceived access to water to predict percentage self-reported time ill at the individual-level. Three of these independent variables pertain to quantity and three to reliability. For each model, one measure of water security was included as the independent variable of interest and percentage time ill as the dependent variable, adjusted for age, nutritional status, type of toilet facility (categorical variable), hygiene indicator scores (continuous variable), wealth status (ordinal variable), and the two interaction terms as independent variables. All models accounted for potential non-independence of percentage self-reported time ill for participants within the same household. An intra-class correlation coefficient (ICC) was used to assess and cluster robust standard errors to account for this potential non-independence. Results are reported as standardised β coefficients, with relevant 95%CIs and p-values. All analyses were conducted using Stata v13 software.

3. Results

Over the four-month study period, eight households were lost to follow-up as they moved outside the study area. Therefore, a total of 92 households (509 individuals) were included in the final analyses. Participants were observed for an average of 102 days. Participants reported illness, on average, only 4% of the observed time (min 0%, median 0%, max 70%, sd 8%). In fact, 64% of participants did not report any symptoms over the observation period. As expected, children < 5 years had 40% higher rate of illness compared to others. The most common reported symptom was 'Fever', a term often used to describe malaria-related symptoms in the region. Figure 2 depicts the trends in self-reported symptoms over the 16-week period, with total monthly rainfall. A clear increase in self-reported diarrhea, fever and skin symptoms can be seen for the March time-period. However, we are unable to determine the temporal relationship between changes in rainfall and self-reported health due to rainfall being reported as a monthly total.

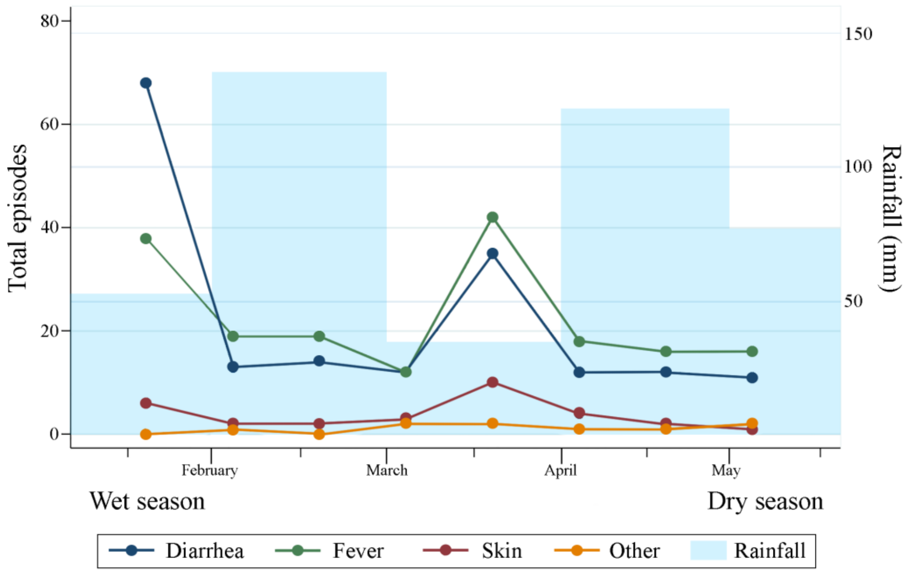

Figure 2. Self-reported symptoms over the study period and total monthly rainfall

Table 1. Descriptive statistics of study participants by illness status

Characteristics		No reported illness *n = 331*	Reported illness *n = 178*	All *n = 509*
Ethnicity, % (n)				
	Bahima	67.3 (109)	32.7 (53)	31.8 (162)
	Bairu	62.3 (172)	37.7 (104)	54.2 (276)
	Other	70.4 (50)	29.6 (21)	14 (71)
Age, % (n)				
	< 5 years	53.1 (52)	46.9 (46)	19.2 (98)
	5-14 years	75.5 (117)	24.5 (38)	30.1 (155)
	15-24 years	79.0 (64)	21.0 (17)	15.9 (81)
	25-44 years	57.5 (69)	42.5 (51)	23.6 (120)
	45-64 years	62.2 (23)	37.8 (14)	7.3 (37)
	65+ years	33.3 (6)	66.7 (12)	3.5 (18)
Malnourished, % (n)				
	< 5 years old	52.0 (13)	48.0 (12)	25.5 (25)
	5+ years old	75.7 (28)	24.3 (9)	9.0 (37)
Sex, % (n)				
	Female	62.2 (158)	37.8 (96)	49.9 (254)
	Male	67.8 (173)	32.2 (82)	50.1 (255)
Water source type, % (n)				
	Borehole	59.5 (88)	40.5 (60)	29.1 (148)
	Unprotected dug well	65.2 (120)	34.8 (64)	36.1 (184)
	Rainwater	75.5 (120)	24.5 (39)	29.7 (151)
	Other	42.3 (11)	57.7 (15)	5.1 (26)

NOTE: ROW PERCENTAGES FOR FIRST TWO COLUMNS OF DATA; COLUMN PERCENTAGES FOR THE THIRD COLUMN.

Table 1 depicts descriptive statistics for participants by illness status. Generally, the sample was young, evenly split by sex, majority of the ethnicity Bairu, and expected levels of malnutrition (25.5% of those under 5 years were classed as malnourished). When comparing those who reported any illness to those who did not, 'other' ethnicity followed by Bahima had the largest percentage of no self-reported illness. As expected, those over 65 years (67%) and those under 5 years (47%) had the highest proportions of self-reported illness among the age groups. Somewhat unexpectedly, there was also a relatively high proportion of those aged 25-44 years who reported illness (43%). A larger proportion of males had no reported illness (68%), compared to females (62%).

Table 2 provides descriptive statistics for households based on the three levels of perceived access to water. On average, households resided in the community for 20 years, and most households reported an average level of wealth (54%). Most hygiene indicators showed hygienic environments. Almost all households (89%) reported boiling water (although this was never observed during the course of data collection) and reported using a personal pit latrine (77%).

Households with low perceived access did not own a bicycle and only 17% of households with high perceived access owned a bicycle, compared to 28% with medium perceived access. The average litres collected yesterday/person was highest in the group with medium level perceived access (15 litres/person), although average litres collected yesterday/person could be considered very low in the entire sample. The group with high perceived access could be characterized as primarily relying on rainwater, followed by unprotected dug wells. The group with medium perceived access could be characterized as depending on a borehole, followed by unprotected dug wells. The small group with low perceived access use either unprotected dug wells or a borehole.

Table 2. Descriptive statistics for households by level of perceived access to household water

Household characteristic	Perceived access LOW *n = 3*	Perceived access MED *n = 60*	Perceived access HIGH *n = 29*	Total *n = 92*
Male acting head of household, % (n)	33.3 (1)	76.6 (46)	89.7 (26)	79.3 (73)
Years living in community, mean (sd)	21.0 (11.5)	19.0 (14.7)	22.2 (20.0)	20.0 (16.4)
Household size, mean (sd)	3.7 (0.6)	5.4 (2.4)	6.1 (3.0)	5.5 (2.6)
Self-reported wealth, % (n)				
High	33.3 (1)	18.3 (11)	20.7 (6)	19.6 (18)
Average	0.0 (0)	56.7 (34)	55.2 (16)	54.3 (50)
Low	66.7 (2)	25.0 (15)	24.1 (7)	26.1 (24)
Hygiene indicators, % (n)				
Soap present	100.0 (3)	86.7 (52)	82.8 (24)	85.9 (79)
Hands/fingernails of respondent clean	66.7 (2)	73.3 (44)	79.3 (23)	75.0 (69)
Face of child clean	66.7 (2)	50.0 (30)	65.5 (19)	55.4 (51)
Food storage containers covered	100.0 (3)	65.0 (39)	65.5 (19)	66.3 (61)
Floor of cooking area clean	100.0 (3)	22.8 (21)	55.2 (16)	43.5 (40)
Clean dishes and utensils	100.0 (3)	28.3 (26)	55.2 (16)	48.9 (45)
No faeces or urine on house floor	100.0 (3)	98.4 (59)	100.0 (29)	98.9 (91)
No livestock or poultry in compound	66.7 (2)	56.7 (34)	55.2 (16)	56.5 (52)
Water storage container covered	0.0 (0)	45.0 (27)	10.3 (3)	32.6 (30)
Water storage container narrow neck	100.0 (3)	95.0 (57)	100.0 (29)	96.7 (89)
Water treatment, % (n)				
Boil	66.7 (2)	85.0 (51)	100.0 (29)	89.1 (82)
Filter	33.3 (1)	6.7 (4)	0.0 (0)	5.4 (5)
None	0.0 (0)	8.3 (5)	0.0 (0)	5.4 (5)
Type of toilet facility, % (n)				
Pit latrine, personal	33.3 (1)	75.0 (45)	86.2 (25)	77.2 (71)
Pit latrine, shared	33.3 (1)	20.0 (12)	13.8 (4)	18.5 (17)
Open defecation	33.3 (1)	5.0 (3)	0.0 (0)	4.3 (4)
Bike ownership, % (n)	0.0 (0)	18.5 (17)	5.4 (5)	23.9 (22)
Litres collected yesterday/person, mean (sd)	13.3 (14.4)	14.9 (8.3)	10.7 (5.8)	13.6 (8.0)
Primary source - Borehole, % (n)	1.1 (1)	23.9 (22)	7.6 (7)	32.6 (30)
Primary source - Unprotected dug well, % (n)	2.2 (2)	22.8 (21)	8.7 (8)	33.7 (31)
Primary source - Rainwater collection, % (n)	0.0 (0)	16.3 (15)	15.2 (14)	31.5 (29)
Primary source - Other, % (n)	0.0 (0)	2.2 (2)	0.0 (0)	2.2 (2)
Distance to source, mean km (sd)	1.9 (1.6)	1.7 (2.7)	1.8 (5.2)	1.7 (3.6)
Ranked minutes to source, mean+ (sd)	2.7 (1.5)	2.1 (0.7)	3.2 (0.6)	2.5 (0.9)
Secure water access in last two weeks, % (n)	100.0 (3)	81.0 (47)	75.9 (22)	78.2 (72)
Source does not evaporate, % (n)	66.7 (2)	41.7 (25)	31.0 (9)	39.1 (36)

NOTE: COLUMN PERCENTAGES
+MINUTES RANK: 4 = <10M, 3 = 11-29M, 2 = 30-45M, 1 = 46+M.

On average, households were 1.7 km from water sources (sd 3.6 km), which is above the 1 km threshold considered of great health concern [2]. Likewise, average rank in minutes to source was 2.5 (sd 0.9), which equates to over 30 minutes walking return trip and waiting time to the source, which is the designated threshold considered of great health concern [2]. Most households (78%) did not experience inaccessibility of the source in the last two weeks at the mid-point of the dry season, but only 39% report that the source does not eventually evaporate.

Households reporting perceived low access were few (n = 3). This group included two households with a female acting head of household, smaller average household size (3.7 versus 6.1 in the perceived high access group), and either low (n = 2) or high (n = 1) wealth. In the high perceived access group (n = 29), average ranked minutes to source was lower (3.2, or < 30 minutes), but a larger percentage of households reported inaccessibility of the source in the past two weeks (24%) and a low percentage of households reported that the source does not evaporate (31%).

Significant predictors of perceived better water access were fewer minutes walking to the source ($\beta = 0.52$, $p < 0.001$) and, surprisingly, fewer litres collected yesterday/person ($\beta = -0.22$, $p = 0.039$ (Table 3). Kilometres to source, ownership of source, secure access in the past two weeks and seasonality were not significantly associated with perceived access.

Table 3. Results for separate regression models: Predicting household perceived access to water^

	Predictors of perceived access	Standardised β	95% CI		p
Quantity indicators	Litres collected yesterday/person	-0.22	-0.42	-0.02	0.039
	Kilometres to source	-0.06	-0.15	-0.03	0.168
	Minutes to source+	0.53	0.45	0.61	<0.001
Reliability indicators	Rank in ownership of source++	0.09	0.002	0.18	0.055
	Secure access over past 2 weeks	-0.07	-0.17	0.03	0.145
	Source does not evaporate in dry season	0.02	-0.06	0.10	0.588

^PERCEIVED ACCESS SCALE: 3=VERY HIGH/HIGH, 2=AVERAGE, 1=LOW/VERY LOW
+MINUTES RANK: 4 = <10M, 3 = 11-29M, 2 = 30-45M, 1 = 46+M
++OWNERSHIP RANK: 1=BOSS, 2=PERSONAL, 3=SHARED, 4=PUBLIC.

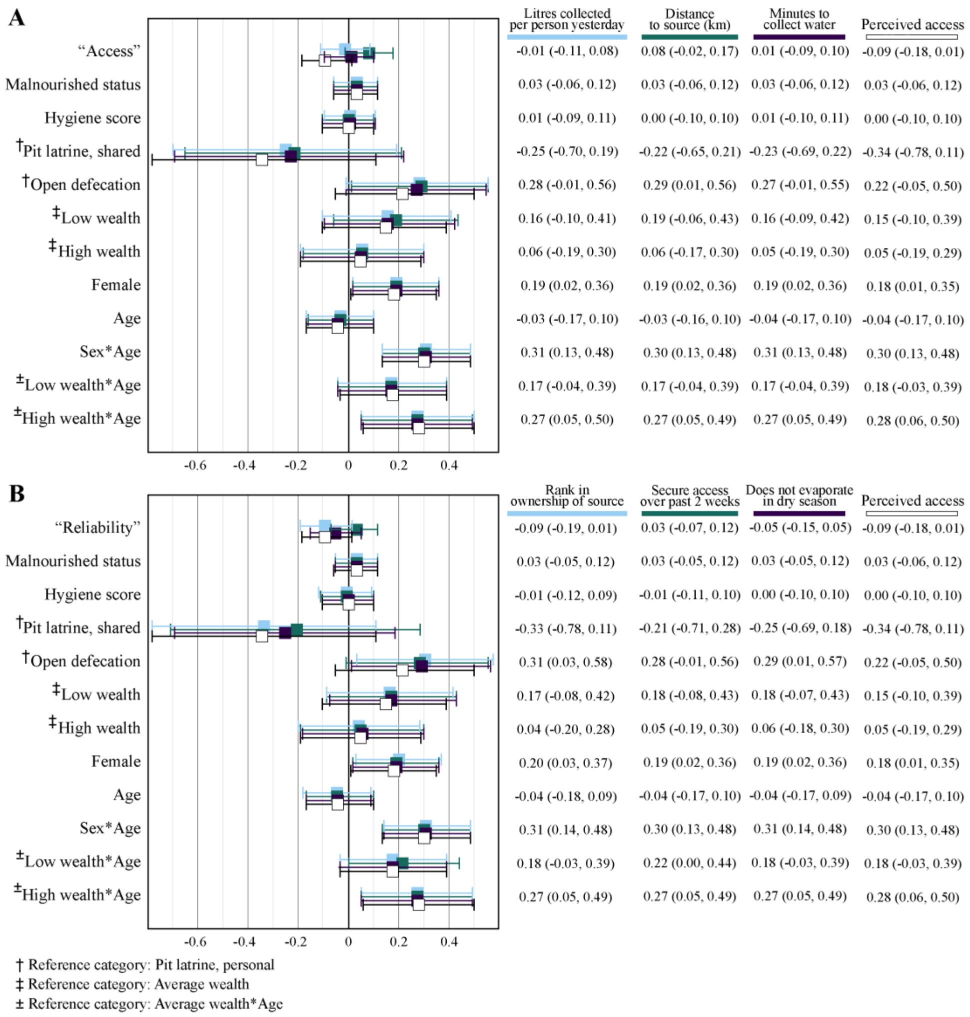

Figure 3. Hierarchical regression model results, showing standardised β coefficients and 95% CIs – comparing the ability to predict percentage time spent ill over the past four months for (A) established measures of quantity versus perceived access, and (B) established measures of reliability versus perceived access

In comparing the ability to predict percentage time ill between established measures of water security versus perceived level of access (Figure 3), we found that only ownership of source and perceived level of access were significant predictors of percentage time spent ill. We found that more private versus more public ownership of the water source was associated with higher percentage time spent ill. Both of these effects were small ($\beta = -0.09$, $p < 0.10$). In other words, moving up one rank in perceived access or having a more public water source were both associated with .09% decrease in percentage time ill.

In all models, the interaction terms were significant. In all but the perceived access model, open defecation was also significantly associated with higher percentage time ill, compared to a personal pit latrine. However, only four households reported open defecation, so these results must be treated cautiously. Somewhat surprisingly, wealth status was not independently, significantly associated with percentage time ill, nor was malnourished status or hygiene score in any of the models. The ICC for the percentage time ill across households suggests that 3-4% of the variation may be explained at the household level across the models.

4. Discussion

In the three communities studied, there were fairly low levels of self-reported symptoms over the four-month observation period, particularly given that most households fell below the thresholds of water access and would be deemed of great health concern [2]. These results are also surprising given that most water sources were ‘unimproved’, which have been shown to be highly contaminated in the study area [23] and elsewhere [37]. By comparison, most other studies in the region were cross-sectional or only included sub-populations (young children). One study reported that in a sample of children under two years, 38% had an episode of fever and 40% had diarrhea within the past two weeks [38]. This study had a mean prevalence of illness among the two year-olds of 9.5% (two-week point prevalence range 2.6 – 15.8%). In fact, percentage self-reported time ill was unexpectedly low for the entire sample, with 64% of participants reported as not being ill. Possible reasons for low levels of self-reported illness may relate to the lack of identifying symptoms in household members or simply lack in reported symptoms. Respondents may not have reported symptoms even when they were experiencing them for a number of reasons, such as not considering the symptom to be ill health, being uncomfortable discussing certain symptoms, or failing to recall symptoms or episodes. The project description and the enrolment and consent script were designed to mitigate against over- or under-reporting of symptoms and the possible belief that illness reporting would lead to an intervention. Rapport was built and staff were trained in probing in an effort to reduce reporting bias.

The symptoms used to obtain these data were locally appropriate terms clearly related to illness and widely recognized. Health data were obtained during a time period with varying rainfall. Other studies report higher incidence of diarrhea in the wet season [29], often related to fecal contaminants washing into surface water sources. Low levels of self-reported illness may also relate to the high hygiene scores observed, meaning that households are maintaining high levels of hygiene which mitigates other drivers of infection. Furthermore, malnutrition status of children under 5 years was similar to other Ugandan findings for stunting (23.8%) and underweight (24.1%) [35] or slightly better than the estimated East Africa prevalence of stunting in this age group in 2010 (42.5%) and slightly worse than the estimated prevalence of underweight (19.6%) [39]. These relatively low levels of illness warrant further exploration, possibly overcome by comparing self-reported and objective measures of illness in this population. Still, self-reported health status may be important in understanding perceptions of health and quality of life, distress and psychosocial health and need not be dismissed in lieu of objective measures.

In comparison to global access to household water, most households have very poor access in terms of walking time, seasonality and most sources being ‘unimproved’. In this study, significant predictors of perceived access were self-reported minutes walking to the source and litres collected yesterday/person. As expected, decreased walking time was associated with higher perceived access (higher rank values equate to shorter times). However, because minutes to source was self-reported, both measures (perceived access and minutes to source) may be homologous measures. Surprisingly, fewer litres collected/yesterday was associated with perceived better access. This may be related to the fact that those with higher perceived access included all participants who collect rainwater. Among these households, water would only be collected for actual use each day since storage is on site.

In comparing the ability to predict percentage time ill between established measures of water security versus perceived level of access, we found that only one established measure was associated with health. More private versus more public or shared ownership of the water source was associated with higher percentage time spent ill. Public versus more private provision of water remains highly contested, particularly in poor settings [40]. Most established measures tested here were self-reported. Perhaps using more objective measures of water security is optimal when evaluating health. We also found that perceived better access was associated with lower percentage time spent ill. The significant effects detected were small, after adjusting for covariates.

To complement our findings related to physical health, future studies may also test the relationship between perceived access and indicators of stress, anxiety and mental health, which is of increasing interest in the water-health research [41]. Given our findings that all households who engaged in rainwater collection perceived their access to be in the middle or high access groups, future studies could evaluate whether rainwater collection serves to increase feelings of control and to reduce stress.

Examining all results together, it is likely that there are other priorities which shape perceived access, which were not measured here or not fully accounted for in analyses. For example, when asked about perceived access to water, meanings may be invoked which conflate access to water to ‘wealth and health’ [42]. There may be actual differences in perceptions and priorities between ethnic groups. For example, agriculturalists tend to be less mobile (with fixed assets like crops), and, in this study, tend to live closer to boreholes. On the other hand, pastoralists in this study rely on surface water sources, and migrate to cope with water scarcity [15], indicating that water priorities include livestock needs. Perhaps, perceived access to water involves balancing the water uses for both human and animal water and this perceived level influences health, due to reliance on livestock for nutrition and as a storage of wealth in times of scarcity. These findings underscore that even in communities characterized by poor access to water by most established measures, wealth, access and health disparities can still be detected.

In exploring what factors might influence perception, there was not a clear gradient in average daily litres of water collected, or in bicycle ownership (as a means to easily collect water), nor was there a clear pattern in primary water source type – except that those with high perceived access were the only group to collect rainwater, which has been recommended as the primary advantageous strategy in settings with poor water infrastructure [43]. Social structures which support or hinder access may be particularly useful for understanding perceived access. The fact that two out of three households reporting low access were headed by females suggests that further work to understand the how gender may hinder access negotiations is important. Future work may usefully untangle the meanings encoded in and complex social structures which influence perceptions of access to water. Articulating the meanings and varying perceptions of access to water is therefore essential to understanding how and why it is used in different ways, and to the resolution of conflicts over access and improving health. This is not to forget the well-established importance of water access improvements resulting in better school performance, household economic development, and health [4] and as such should remain a primary target to reduce water-related health and social inequalities.

This study has limitations. While this study did not measure microbiological or chemical water quality as a dimension of water security, previous research in the study area showed very high levels of contamination for surface sources and indicators of faecal contamination for some groundwater sources [23]. Future studies could combine measurement of perceived access, and all three dimensions of water security – quality, quantity and reliability – as important health determinants. The objectively measured distance (km to source from home) used here did not account for routes taken from home to the water source or the hilly terrain of the study area. Future studies could make better use of GPS technologies to track routes taken from home to the water source and elevation changes en route. The use of proportional population sampling meant that analyses by community would not be robust (as two villages had small populations). Only one village had access to a permanent lake, yet it is unknown whether other factors related to living in particular villages influenced health. In addition, eight households were lost to follow-up, due to migration outside the three study communities. These households may be different from the remainder of the sample population in unknown ways that might affect the association between perceived access and health. However, due to their small contribution to the sample size, the observed associations would be unlikely to change. Last, the reliance on self-reported symptoms and the possible fatigue of participants may have influenced the health data. Similarly, there is likely still some residual confounding by wealth. Future studies, with larger sample sizes, could usefully evaluate differences in perceived access over time and wealth measures by ethnicity, using both self-reported and objective measures of health longitudinally.

5. Conclusions

This study found that higher perceived access was associated with modestly lower percentage self-reported time spent ill over a four-month period in rural, southwestern Uganda. More public ownership of the water source was also associated with higher percentage time spent ill. Yet, other established measures of water security were not associated with health. While it is important not to lose sight of the ultimate goal of equitable provision of safe, adequate and reliable water for households, an important first step in improving health may be to evaluate priorities and perceptions of access, which appear to vary by livelihoods and ethnicity. These social structures and may be particularly salient to avoid conflict into the future, with projected water shortages across sub-Saharan Africa.

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Ethical Approval

Ethical approval was granted by the University of Washington (HSD # 07-5209-J01), Mbarara University and Uganda National Centre for Science and Technology.

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