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# The Household Water InSecurity Experiences (HWISE) Scale: development and validation of a household water insecurity measure for low-income and middle-income countries

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## ABSTRACT

**Objective** Progress towards equitable and sufficient water has primarily been measured by population-level data on water availability. However, higher-resolution measures of water accessibility, adequacy, reliability and safety (ie, water insecurity) are needed to understand how problems with water impact health and well-being. Therefore, we developed the Household Water InSecurity Experiences (HWISE) Scale to measure household water insecurity in an equivalent way across disparate cultural and ecological settings.

**Methods** Cross-sectional surveys were implemented in 8127 households across 28 sites in 23 low-income and middle-income countries. Data collected included 34 items on water insecurity in the prior month; socio-demographics; water acquisition, use and storage; household food insecurity and perceived stress. We retained water insecurity items that were salient and applicable across all sites. We used classical test and item response theories to assess dimensionality, reliability and equivalence. Construct validity was assessed for both individual and pooled sites using random coefficient models.

**Findings** Twelve items about experiences of household water insecurity were retained. Items showed unidimensionality in factor analyses and were reliable (Cronbach's alpha 0.84 to 0.93). The average non-invariance rate was 0.03% (threshold <25%), indicating equivalence of measurement and meaning across sites. Predictive, convergent and discriminant validity were also established.

**Conclusions** The HWISE Scale measures universal experiences of household water insecurity across low-income and middle-income countries. Its development ushers in the ability to quantify the prevalence, causes and consequences of household water insecurity, and can contribute an evidence base for clinical, public health and policy recommendations regarding water.

## Key questions

### What is already known?

- Household water insecurity, or the inability to access and benefit from adequate, reliable and safe water, is widely recognised as a threat to human health and well-being.
- Current household-level measurements of water focus on only a subset of the components of water insecurity or are not cross-culturally validated.

### What are the new findings?

- We developed the 12-item Household Water InSecurity Experiences (HWISE) Scale based on data from 8127 households across 28 sites in 23 low-income and middle-income countries.
- The HWISE Scale is reliable, valid and equivalently measures the multiple components of water insecurity (adequacy, reliability, accessibility, safety) across disparate cultural and ecological settings.
- The HWISE Scale is simple to implement (approximately 4 min to administer) and scores are easy to calculate.

### What do the new findings imply?

- The HWISE Scale can be used to monitor and evaluate water insecurity, identify vulnerable subpopulations for maximally effective resource allocation and measure the effectiveness of water-related policies and interventions.

## INTRODUCTION

Human health is predicated on water. Problems with water availability (shortage, flooding), accessibility (affordability, reliability) and quality (chemicals, pathogens) directly contribute to the global burden of disease.[1–3] Water-related issues also create the conditions that undermine health by lowering economic productivity[4 5]; triggering and perpetuating domestic, social, intercommunal and political tensions and conflicts[4]; and reinforcing environmental, social and gender inequities.[5 6] These problems are projected to become more frequent and severe due to climate change, unequal resource distributions and persistent degradation of water quality and infrastructure.[4 7 8] As such, numerous national institutions and international agencies have declared meeting the challenges of declining and inequitable water supplies to be an urgent priority.[4 7] Further, safe water in sufficient quantities is implicated in most of the Sustainable Development Goals (SDGs).

Progress towards equitable and sufficient water has been primarily assessed using measures of water availability, often at the state or regional level.[9] These indicators have been useful to numerous governmental agencies and scientific disciplines, but mask heterogeneity within populations, thereby obscuring the individual health, economic and psychosocial burdens of water problems. In other words, water availability is a fundamental and necessary component of our understanding about water, but is not sufficient for understanding who has adequate access to water for all household uses.

The concept of household water insecurity has emerged as a powerful way to better 'understand the interactions among water's various characteristics and functions'.[3] Household water insecurity, defined as the inability to access and benefit from adequate (ie, appropriate quantities of water for all household uses), reliable and safe water for well-being and a healthy life, considers the multiple components of water and does so at the level at which they are experienced (ie, by individuals and households).[10]

Several existing metrics consider some of these components of household water insecurity. For instance, the Joint Monitoring Programme's (JMP) core questions on drinking water, sanitation and hygiene have produced higher-resolution information by collecting household-level data on water quality (primary drinking water source, source of other water, drinking water treatment) and accessibility (roundtrip time to primary drinking water source).[11] With these data, it is possible to calculate the proportion of the population with access to a safely managed drinking water source, which is currently the indicator for measuring progress towards SDG 6.1. The JMP core questions do not capture a number of critical components of household water insecurity, however, including adequacy across uses, acceptability, affordability or reliability.[12 13]

Site-specific scales have thus been developed to more comprehensively measure all aspects of household water insecurity, including those not measured by JMP.[14–18] Because these scales were each developed to fit a specific context, however, their scalability, generalisability and cross-cultural equivalence have not been established. This inability to validly measure household water insecurity in a cross-culturally equivalent way is a significant scientific gap that has spurred calls for higher-resolution data, including by the United Nations High-Level Panel on Water.[3 7]

We therefore set out to create the first tool for comparative analysis of household water insecurity to be able to identify exactly who is water insecure, to what extent, and where and when it occurs. Here we report the development of the survey instrument and its validation across 28 disparate settings in low-income and middle-income countries.

## METHODS

### Data collection

The study protocol detailing site and participant selection and data collection is available elsewhere.[19] Briefly, sites in low-income and middle-income countries were selected using purposive sampling to maximise heterogeneity of region, geography, culture, infrastructure, seasonality and specific problems with water (figure 1). We sought to survey at least 250 households per site.[19] Random sampling of households was used in the majority of sites (table 1). The final sample included 8127 households across 28 sites in 23 low-income and middle-income countries (table 1).

Adults were eligible for survey inclusion if they considered themselves to be knowledgeable about water acquisition and use in their household. Participants gave oral or written informed consent.[19]

A comprehensive survey module was developed to capture experiences across relevant components of water insecurity (eg, acceptability, use).[10 19] It consisted of 32 items developed based on literature review[10] and fieldwork.[14 15 18] The content and face validity of these items were assessed at each site.[19] The items elicited frequency of experiences within the prior 4 weeks: 'never' (0 times), 'rarely' (1–2 times), 'sometimes' (3–10 times), 'often' (11–20 times), 'always' (more than 20 times), 'not applicable', 'don't know' or refused (online supplementary table 1). A 4-week recall period was selected based on ethnographic work,[10] empirical evidence from Kenya[14] and a large body of evidence from food insecurity literature.[20]

After 5 months of data collection, the water insecurity items were revised (online supplementary table 1). Modifications included slight rephrasing of 18 items to improve comprehension by participants and to elicit experiences related to water overabundance; two new questions were added in an effort to capture cultural components of water (online supplementary table 1).[19] Sites in which the original water insecurity module was used are referred to as 'module version 1' sites; those using the revised water insecurity module are referred to as 'module version 2' sites.

After obtaining informed consent, trained local enumerators surveyed participants on socio-demographics; water acquisition, use and storage, including


**Figure 1** Map of 28 Household Water InSecurity Experience study sites across 23 low-income and middle-income countries. (1) Module version 1 implemented; (2) module version 2 implemented. Image credit: Frank Elavsky, Northwestern University Information Technology, Research Computing Services.

JMP survey items[11]; experiences of water insecurity; household food insecurity using the Household Food Insecurity Access Scale[21]; and perceived stress using the modified four-item Perceived Stress Scale.[22] In module version 2, we also included items on perceived water status in the community using a ladder scale (range 1–10) and satisfaction with water situation (1–5 Likert scale). Surveys were conducted in the participants' preferred language and lasted approximately 45 min. Cross-sectional data collection occurred from March 2017 to July 2018.[19] Data were uploaded to a centralised aggregate server (Google App Engine) and cleaned using a standard protocol.[19]

## Analysis

Analyses were guided by both classical test theory[23] and item response theory (Rasch),[24] following best practices for scale development.[25] We performed all analyses (eg, descriptive, factor analyses, tests of dimensionality) using four response categories ['never' (scored as 0), 'rarely' (scored as 1), 'sometimes' (scored as 2), 'often/always' (scored as 3)]; 'often' and 'always' were collapsed because 'always' was very rarely affirmed. In sensitivity tests, the analyses were reprised with responses dichotomised ('never' vs any affirmation), but since neither the significance nor direction of the results differed, the results based on polytomous scoring (ie, four categories) are presented.

The first step of Household Water InSecurity Experience (HWISE) Scale creation was item retention, which was based on theory informed by empirical evidence from descriptive statistics, inter-item and intra-item correlations, factor analysis and Rasch analysis. Any item with greater than 30% missing values within a site (reflecting inapplicability of the item) was considered insufficiently universal to enable cross-site comparisons—a primary goal of the study—and thus removed from analysis.[19]

Multidimensionality was tested using exploratory factor analysis (EFA) and Rasch techniques. EFA was conducted using oblique rotation to explore the latent structure of the items for each site.[26] Items that did not meet established cut-offs and those with cross-loadings across multiple sites were removed.[25] For both exploratory and confirmatory factor analysis, we used the following standard indices of approximate model-data fit: Bentler's Comparative Fit Index (CFI), the root mean square error of approximation (RMSEA) and the standardised root mean square residual (SRMR). Satisfactory fit was determined using recommended combinational cutoffs of (a) CFI≥0.95 and SRMR ≤0.08 or (b) RMSEA ≤0.06 and SRMR ≤0.08.[27]

Once dimensionality of the retained items was determined, Guttman ordering (ie, a reproducible hierarchy of item severity across sites, an assumption on which Rasch analyses are based) was evaluated. Internal reliability was also tested using Cronbach's alpha (>0.80).

We then assessed equivalence, that is, measurement invariance across sites. Although multiple group confirmatory factor analysis is a standard method for assessing invariance, it is not useful when there are many groups with poor fit at the scalar level.[26] Given that this was evident in our data, the alignment optimisation technique

**Table 1** Overview of household water insecurity experiences study sites, by World Bnk region

| World Bank region | Site (n) | Water insecurity module version | Urbanicity | Sampling strategy | Season of data collection | Respondent sex, % female | Respondent age, mean (SD) | Household size, mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Africa | Accra, Ghana (229) | 1 | Urban | Stratified random | Rainy season | 78.2 | 37.3 (12.9) | 6.2 (5.2) |
| | Lagos, Nigeria (239) | 1 | Urban | Multi-stage random | Rainy season | 73.5 | 39.2 (10.8) | 4.8 (3.1) |
| | Kahemba, DRC (392)* | 1 | Rural | Cluster randomised control trial | Dry season | 65.6 | 38.5 (14.7) | 6.7 (2.7) |
| | Bahir Dar, Ethiopia (259) | 1 | Rural | Stratified random | Rainy season | 100 | 36.0 (13.0) | 5.0 (2.2) |
| | Singida, Tanzania (564) | 1 | Rural | Purposive, community led | Dry season | 56.7 | 32.8 (9.1) | 6.2 (2.2) |
| | Lilongwe, Malawi (302) | 1 | Peri-urban | Cluster random | Neither rainy nor dry season | 86.8 | 32.3 (12.0) | 5.2 (2.3) |
| | Arua, Uganda (250) | 1 | Rural | Cluster random | Rainy season | 85.6 | 36.5 (14.8) | 6.1 (2.9) |
| | Kisumu, Kenya (247) | 1 | Rural | Simple random | Neither rainy nor dry season | 81.3 | 39.3 (15.5) | 5.5 (2.8) |
| | Kampala, Uganda (246) | 1 | Urban | Purposive | Dry season | 69.1 | 37.3 (11.2) | 5.4 (3.0) |
| | Morogoro, Tanzania (300) | 2 | Urban and peri-urban | Cluster random | Rainy season | 78.3 | 40.1 (14.9) | 6.2 (3.5) |
| East Asia and Pacific | Upolu, Samoa (176)† | 1 | Urban and peri-urban | Purposive | Across multiple seasons | 57.5 | 50.9 (9.8) | n.d. |
| | Labuan Bajo, Indonesia (279) | 2 | Urban | Cluster random | Dry season | 44.8 | 38.2 (11.3) | 4.6 (1.9) |
| Europe and Central Asia | Dushanbe, Tajikistan (225) | 1 | Urban | Cluster random | Dry season | 73.3 | 41.0 (14.4) | 5.5 (2.7) |
| Latin America and the Caribbean | Ceará, Brazil (254) | 1 | Urban | Cluster random | Neither rainy nor dry season | 70.1 | 43.2 (16.1) | 4.0 (1.8) |
| | Mérida, Mexico (250) | 1 | Urban | Cluster random | Dry season | 63.2 | 45.3 (15.5) | 4.7 (2.7) |
| | Acatenango, Guatemala (101)† | 1 | Peri-urban | Cluster random | Dry season | 93.0 | 48.0 (16.1) | 4.8 (2.1) |
| | Honda, Colombia (196)*† | 1 | Peri-urban | Cluster random | Rainy season | 63.6 | 52.2 (15.2) | 3.4 (1.9) |
| | Torreón, Mexico (249) | 2 | Urban | Simple random | Middle/end of dry season | 73.1 | 46.3 (16.6) | 3.7 (1.9) |
| | San Borja, Bolivia (247) | 2 | Rural | Simple random | Dry season | 58.6 | 40.0 (14.6) | 5.8 (3.0) |
| | Chiquimula, Guatemala (314) | 2 | Rural | Systematic random | Middle/end of dry season | 86.6 | 38.8 (15.0) | 6.1 (2.5) |
| | Gressier, Haiti (292) | 2 | Peri-urban | Stratified random | Dry season | 98.6 | 36.1 (14.0) | 5.0 (2.2) |
| | Cartagena, Colombia (266) | 2 | Urban | Stratified random | Dry season | 69.2 | 40.8 (15.1) | 5.3 (2.8) |

Continued

Table 1 Continued

| World Bank region | Site (n) | Water insecurity module version | Urbanicity | Sampling strategy | Season of data collection | Respondent sex, % female | Respondent age, mean (SD) | Household size, mean (SD) |
|---|---|---|---|---|---|---|---|---|
| Middle East and North Africa | Beirut, Lebanon (573) | 2 | Urban | Cluster random | Rainy season | 63.8 | 42.9 (14.9) | 4.2 (1.9) |
| | Sistan and Balochistan, Iran (306) | 2 | Urban, peri-urban and rural | Stratified random | Rainy season | 99.0 | 33.3 (10.9) | 5.4 (2.3) |
| South Asia | Kathmandu, Nepal (263) | 1 | Urban | Cluster random | Rainy season | 71.5 | 41.4 (13.3) | 4.8 (2.2) |
| | Pune, India (180)† | 1 | Urban | Parallel assignment, non-randomised | Across multiple seasons | 100 | 29.5 (5.8) | 4.3 (2.7) |
| | Punjab, Pakistan (235) | 2 | Rural and peri-urban | Cluster random | Dry season | 57.5 | 35.9 (10.1) | 8.1 (2.8) |
| | Rajasthan, India (248) | 2 | Urban | Stratified random | Dry season | 27.0 | 41.9 (13.1) | 6.3 (3.6) |

*Dropped from analysis because of problems with survey questionnaires.
†Dropped from analysis for achieving less than 90% of the a priori sample size.

was a more suitable method for estimating group-specific factor means and variances because it does not require exact measurement invariance.[26] Therefore, using the alignment optimisation technique, we assessed invariance for aligned threshold parameters and loadings for scale items. Scales were considered approximately invariant if less than 25% of the items' parameters were non-invariant and did not compromise the reliability of mean comparison across sites.[28]

Construct validity was assessed for both individual and pooled sites using random coefficient models, to account for variation by site. Predictive construct validity was assessed by determining if HWISE Scale scores predicted food insecurity, perceived stress, satisfaction with water situation and perceived water standing in the community. Convergent construct validity was tested by examining the association between HWISE Scale scores and time to water source. Discriminant construct validity was tested using differentiation between 'known groups', that is, groups known to have different water situations, such as those who have been injured while acquiring water versus those who have not. We assessed differences in means between 'known groups' using Student's *t*-tests.

Once the scale was finalised, we sought to identify a standardised threshold for defining households as water insecure or not, to assess prevalence. We sought a cut-point that would achieve a wide distribution of prevalence across sites and be sensitive to differences between known groups within sites. We evaluated the sensitivity of provisional cut-points by determining if food insecurity, perceived stress, satisfaction with water situation and perceived water standing in the community differed significantly between households who were classified as water insecure and those who were not, using regression models.

Three software packages were used: Stata V.14 (StataCorp); M*plus* V.8 (Muthén & Muthén, Los Angeles, California, USA) for classical test theory analyses; and WINSTEPS (Winsteps, Beaverton, Oregon, USA) for item response theory (Rasch) analyses.

### Participant involvement

Although formative work drew on ethnographic research that included participant involvement,[10] no participants were involved in study design, implementation or dissemination, including the writing of this manuscript.

## RESULTS

### Descriptive statistics

Surveys were implemented in 8127 households across 28 sites that were heterogeneous in geography, infrastructure and season (table 1). The frequency of affirmation of water insecurity experiences differed vastly by site (online supplementary figure 1). Of the 28 sites surveyed, three were dropped from analysis for achieving less than 90% of the a priori sample size (table 1). Additionally, two sites (Honda, Colombia and Kahemba, Democratic Republic

Table 2 Rationale and evidence for dropping water insecurity module items

| Analysis informing decision | Item dropped (item number)* | Rationale |
|---|---|---|
| **Descriptive statistics** | **Loan water** (1.24) | Not salient |
| | **Too sick or weak** (1.30) | Not salient |
| | **Treat water** (1.20) | Not salient |
| | **Take medications** (1.29) | Too rare |
| | **Crops** (1.5, 2.6) | Not universal |
| | **Livestock** (1.6, 2.7) | Not universal |
| | **Caring for children** (1.10) | Not universal |
| | **Miss school** (1.12, 2.11) | Not universal |
| | **Wash face and hands of children** (1.16, 2.15) | Not universal |
| | **Worry about safety of person** (1.2, 2.4) | Not universal |
| | **Lacked money** (1.8, 2.9) | Not universal |
| | **Nowhere to buy** (1.9, 2.10) | Not universal |
| | **Earning money** (1.7, 2.8) | Not universal |
| **Item correlations (EFA**) | **Quarrel - neighbours** (1.25, 2.22) | Poor item correlation coefficients |
| | **Quarrel - household** (1.26, 2.23) | Poor item correlation coefficients |
| | **Taste bad** (1.21, 2.19) | Poor item correlation coefficients |
| | **Drank unsafe** (1.22, 2.20) | Poor item correlation coefficients |
| | **Borrow** (1.23, 2.21) | Poor item correlation coefficients |
| | **Moving** (1.3, 2.28) | Poor item correlation coefficients |
| **Item correlations (Rasch**) | **Attend social events** (1.19, 2.18) | Redundant (highly correlated with “day interrupted”) and poor phrasing |
| | **Chores** (1.11) | Redundant (highly correlated with “wash clothes”) and poor phrasing |
| | **Preferred** (2.2) | Redundant (highly correlated with “worry about enough”) and poor phrasing |

*Complete item numbering in online supplementary table 1.

of Congo) were excluded because of issues that occurred with translation.

## Item retention

Of the 34 potential scale items, 13 items were discarded for being insufficiently salient to the concept of household water insecurity (n=3), being affirmed rarely (n=1) and/or pertaining to phenomena that did not occur universally across sites (n=9) (table 2, online supplementary figure 1).

With the remaining 21 items, a one-factor (ie, all 21 items in one dimension) solution was assessed using EFA. The resultant model had poor fit indices. Therefore, a two-factor solution was also evaluated using EFA. The two-factor solution was composed of ‘access’ and ‘use’ domains that were established through consensus with the analytic team. The two factors fit the data well but were highly correlated (r=0.6–0.9), suggesting that retaining two factors would be redundant. Given this, a one-factor solution was assumed, and nine more items were eliminated based on poor inter-item correlations (table 2).

## Dimensionality and reliability

Unidimensionality of the 12 items was established for each site individually (online supplementary table 2). Cronbach’s alpha values were calculated within sites and then aggregated across sites; values ranged from 0.84 to 0.93, suggesting strong reliability (online supplementary table 2). The 12 items did not exhibit Guttman ordering across sites (ie, Rasch severity scores were not similar; online supplementary figure 2). As such, Rasch became ancillary for subsequent analyses.

## Equivalence

Model fit indices from multi-group confirmatory factor analysis indicated that the factor structure exhibited configural invariance, that is, the latent factor was associated with the same items across sites (module 1: RMSEA=0.08, CFI=0.96; module 2: RMSEA=0.08, CFI=0.97). Thus, alignment optimisation was an appropriate next step.

Alignment optimisation matrices indicated that items were invariant within module versions 1 and 2; that is, the measurement and meaning associated with the items were

Table 3 Tests of HWISE Scale validity using random coefficient regression models, controlling for sites

| | Coefficient (95% CI) | SD (residual) | ICC |
|---|---|---|---|
| Predictive validity† | | | |
| Satisfaction with water situation‡ | −0.07 (-0.08 to -0.06)*** | 1.12 | 0.19 |
| Perceived water standing in community§ | 0.16 (0.12 to 0.20)*** | 2.26 | 0.12 |
| 4-item Perceived Stress Scale score (0–16) | 0.05 (0.01 to 0.09)** | 2.27 | 0.22 |
| Household Food Insecurity Access score (0–27) | 0.38 (0.29 to 0.47)*** | 5.61 | 0.32 |
| Convergent validity¶ | | | |
| Time (minutes) to water source | 0.06 (0.02 to 0.09)** | 6.82 | 0.41 |
| Discriminant validity¶ | | | |
| If injured while fetching water | 4.51 (2.21 to 6.80)*** | 7.28 | 0.37 |

*P<0.05; **P<0.01; ***P<0.001.
†HWISE Scale score is the main independent variable.
‡Range is 1–5, 5=very satisfied.
§Scored using a ladder with range 1–10,1=highest standing.
¶HWISE Scale score is the dependent variable.
HWISE, Household Water InSecurity Experiences; ICC, intraclass correlation coefficient.

the same. The average non-invariance rate was 0.01% for both the aligned intercept and factor loadings in module version 1 and 0.03% in version 2 (online supplementary table 3), which is below the cut-off of 25%. These results establish the comparability of the measurement and meaning of the HWISE Scale across sites.

### Construct validity

With the 12-item scale (total score range 0–36, where higher scores indicate greater household water insecurity), we assessed construct validity. This was established using data from module version 2 sites; module version 1 only had 11 of the final 12 HWISE Scale items (table 1, online supplementary table 1).

In terms of predictive validity, higher HWISE Scale scores were significantly associated with lower water satisfaction, lower perceived water standing in the community, greater perceived stress and greater food insecurity in random coefficient regression models (table 3). For example, for every 10 points higher on the HWISE Scale, individuals were expected to score 3.8 points higher on the Household Food Insecurity Access Scale.

Convergent validity was supported by a statistically significant positive association between HWISE Scale scores and minutes to water source, in a random coefficient regression model (table 3; B=0.06, 95% CI: 0.02 to 0.09, p≤0.01). In other words, for every 10 additional minutes spent travelling to a water source, a household would score 0.6 points higher on the HWISE Scale. The relationship remained significant when controlling for urbanicity.

To assess discriminant validity, we examined the differences between HWISE Scale scores for households that experienced injury during water acquisition vs those that did not. Injury while fetching water was associated with a 4.51-point increase in HWISE Scale scores (95% CI: 2.21 to 6.80, p≤0.001) (table 3). In light of demonstrated validity, we retained all 12 of the provisional items for inclusion in the HWISE Scale (table 4).

A useful feature of scales is the ability to generate prevalence estimates. Therefore, using these 12 items, we sought to establish an appropriate cut-off for household water insecurity. To do this, we explored the distribution of HWISE Scale scores by food insecurity, perceived stress and perceived water standing. Inflection points consistently appeared at HWISE Scale scores of 10, 12 and 20. We therefore evaluated if these three cut-points captured heterogeneity in prevalence of water insecurity across sites (online supplementary figure 3).

At a cut-point of 12, a household experiencing half of the 12 HWISE Scale items ‘sometimes’ in the past 4 weeks would be considered water insecure. Using this cut-point, water-insecure individuals had lower satisfaction with water and perceived water standing, as well as higher perceived stress and food insecurity scores, than those who were not (online supplementary table 4). Similarly, the odds of being water insecure increased by 2% for every minute increase in time to primary water source and 266% if injured while fetching water (online supplementary table 4). A cut-point of 12 also distinguished between subpopulations with expected differences in water insecurity within sites, for example, households within and outside refugee camps in Beirut, Lebanon and households in neighbourhoods with greater and less water availability in Chiquimula, Guatemala. Therefore, an HWISE Scale score of 12 or higher was selected as a reasonable provisional indicator for household water insecurity.

## DISCUSSION

We present the development and validation of the first scale that quantifies experiences of household water insecurity in an equivalent way across low-income and

Table 4 Items, responses and scoring of the Household Water InSecurity Experiences Scale

| Label | Item* |
|---|---|
| Worry | In the last 4 weeks, how frequently did you or anyone in your household **worry** you would not have enough water for all of your household needs? |
| Interrupt | In the last 4 weeks, how frequently has your main water source been **interrupted** or limited (eg, water pressure, less water than expected, river dried up)? |
| Clothes | In the last 4 weeks, how frequently have problems with water meant that **clothes** could not be washed? |
| Plans | In the last 4 weeks, how frequently have you or anyone in your household had to **change schedules or plans** due to problems with your water situation? (Activities that may have been interrupted include caring for others, doing household chores, agricultural work, income-generating activities, etc.) |
| Food | In the last 4 weeks, how frequently have you or anyone in your household had to **change what was being eaten** because there were problems with water (eg, for washing foods, cooking, etc.)? |
| Hands | In the last 4 weeks, how frequently have you or anyone in your household had to go without **washing hands** after dirty activities (eg, defecating or changing diapers, cleaning animal dung) because of problems with water? |
| Body | In the last 4 weeks, how frequently have you or anyone in your household had to go without **washing their body** because of problems with water (eg, not enough water, dirty, unsafe)? |
| Drink | In the last 4 weeks, how frequently has there not been **as much water to drink** as you would like for you or anyone in your household? |
| Angry | In the last 4 weeks, how frequently did you or anyone in your household feel **angry** about your water situation? |
| Sleep | In the last 4 weeks, how frequently have you or anyone in your household gone to **sleep thirsty** because there wasn't any water to drink? |
| None | In the last 4 weeks, how frequently has there been **no useable or drinkable water** whatsoever in your household? |
| Shame | In the last 4 weeks, how frequently have problems with water caused you or anyone in your household to **feel ashamed**/excluded/stigmatised? |

*Responses to items are: never (0 times), rarely (1–2 times), sometimes (3–10 times), often (11-20 times), always (more than 20 times), don't know and not applicable/I don't have this. Never is scored as 0, rarely is scored as 1, sometimes is scored as 2 and often/always are scored as 3.

middle-income countries. The scale uses simply worded questions to probe about household water access, availability and use, and can be administered in approximately 4 min. The ability of the HWISE Scale to comparably measure key universal household water insecurity experiences across diverse geographic, cultural and water-provisioning contexts satisfies an urgent need articulated by policymakers, governments and scholars.[7 29]

By quantifying experiences across multiple components of household water insecurity (accessibility, adequacy, reliability and safety), the HWISE Scale represents a fundamental advance in our ability to measure this phenomenon. For other global health issues, the advent of high-resolution, experiential measures has informed basic science, public health and international policy. For instance, food insecurity was only solely assessed using food *availability* via national-level and regional-level food balance sheets, which are analogous to current measures of water availability.[9] In the last 25 years, the inclusion of food *access, use* and *acceptability* in experienced-based scales (eg, Food Insecurity Experience Scale,[30] Household Food Insecurity Access Scale[21]) has provided a comparable measure for monitoring and evaluating food insecurity worldwide.[20]

This more comprehensive measurement of food insecurity has been transformative. Specifically, the advent of high-resolution measures of food insecurity has increased the number and rigour of studies of food insecurity; revealed its deleterious consequences for physical and mental health[31] and cognitive development[32 33]; and informed the development of programmes and policies that address food insecurity.[34 35] The creation of household-level measures of food insecurity made it unmistakable that food insecurity is highly prevalent and threatens health and economic productivity, and ultimately served as a tool to help mitigate food insecurity.

The use of the HWISE Scale could be similarly transformative for our understanding of water insecurity. Specifically, the scale permits comparative studies that quantify the multiple components of water insecurity with higher resolution than currently possible, allowing for the identification of global inequities, as well as vulnerable sub-populations within communities. The scale also has the potential to identify determinants of water insecurity and assess the health, economic and psychosocial consequences of household water insecurity, including food insecurity.[36] Furthermore, the scale could be used to monitor trends in water insecurity over time, such as how it is shaped by macro-level social, economic and political shifts; climatic variability; and local shocks, such as extreme weather events or contamination. These scale data can, in turn, be used to select water-related programmes, technologies and policies to implement, and to evaluate their impacts and cost-effectiveness. The scale's ease-of-use makes it appropriate for adoption in both community-led self-evaluation efforts and for large-scale monitoring and evaluation.

The HWISE Scale can also complement existing indicators to more comprehensively measure progress towards the SDGs. Current JMP survey items provide critical data on the quality and accessibility of drinking water sources,[11] but they do not quantify other necessary components of water insecurity, including reliability, acceptability or adequacy across multiple uses. As such, the prevalence of problems associated with securing and benefiting from safe water could be significantly underestimated.[12 13]

For instance, a household classified as having a safely managed drinking water source using the current JMP service ladder may not be able to reliably access this source (eg, due to intermittent supply, water rationing, non-functional water technologies, unaffordability). This unreliable access, in turn, can drive households to seek water from a lower-quality secondary source, cause changes in critical water-related activities (eg, food preparation, handwashing) and alter daily routines.[37–41] All of these components of water insecurity would go uncaptured if only the JMP survey items were applied.

Indeed, the proportion of water-insecure households, as identified using the HWISE Scale, is different from and more comprehensive than the proportion using a sub-optimal drinking water source, according to JMP standards (online supplementary figure 4). As such, the unique ability of the HWISE Scale to concurrently measure multiple components of household water insecurity has the potential to provide a more robust assessment of SDG 6, 'ensure access to water and sanitation for all'.

The HWISE Scale is also consistent with the SDG principles of 'universality' and 'leaving no one behind', in that the scale can be easily implemented in low-income and middle-income countries, and the data it generates can be disaggregated to identify vulnerable populations. Further, it satisfies a call for a more holistic conceptualisation of water and sanitation.[42] Just as the prevalence of household food security is an indicator for SDG 2 ('no hunger'), household water insecurity could be a key target for improved health and well-being that can be tracked using the HWISE Scale.

The HWISE Scale captures components of water insecurity that are experienced universally across low-income and middle-income countries. To do this, however, the final scale is necessarily reductionist. Supplemental items or modules tailored to local experiences and evaluation needs may be used to complement the HWISE Scale. For example, agriculture-focused endeavours may retain the items on water for crops, gardens and livestock that were dropped; others may find the items pertaining to children's well-being important (eg, school attendance, bathing; table 2, online supplementary table 1). Further, there are other water insecurity experiences that may be salient in some settings but are not captured in this scale, for example, affordability, which could be measured with additional items.

Strengths of this study include the diversity of sites, rigour of data collection and analytic methods, and use of best practices in scale development. Limitations include that, although samples from each site were sufficiently large and most were random, they were not necessarily representative of the state or country.

Development and validation of the HWISE Scale is only one step toward understanding and mitigating water insecurity. The HWISE Scale must be widely implemented in order to generate data that help to understand and monitor the prevalence, aetiologies and consequences of household water insecurity. A further next step is to evaluate if the HWISE Scale is valid in high-income countries. The tentative cut-point of 12 as the preliminary threshold for defining water-insecure households should also be revisited when there are sufficient data to evaluate relationships with other adverse outcomes, for example, morbidity or agricultural productivity. Lastly, multiple levels of water insecurity could be considered (eg, high vs low water insecurity).

In sum, the HWISE Scale provides a universal, simple measure to comprehensively capture complex, household-level relations between people and water in low-income and middle-income countries. Given that water insecurity is a linchpin in human health disparities and the structural dynamics of poverty and economic development,[2 4 6 7 11 16] the use of the HWISE Scale could be transformative in many arenas. As problems with water become more common and severe, the data that the HWISE Scale generates can guide the international community's ambitious development agenda by contributing an evidence base for clinical, public health and policy recommendations regarding water.

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