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Associations of drinking water access, household water and food security, and mental well-being of prenatal women in low-income, urban neighborhoods of Beira, Mozambique

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a thesis submitted to the Faculty of the
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Abstract

Associations of drinking water access, household water and food security, and mental well-being of prenatal women in low-income, urban neighborhoods of Beira, Mozambique

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Background: Few studies exist that study the influence of drinking water access on mental well-being, but those that do find that unimproved conditions are associated with poorer mental well-being. Quantifying the relationships between drinking water access, water and food security, and mental well-being can inform programs and policies that facilitate health equity. This may be particularly important among prenatal women, as prenatal stress and poor mental well-being has been shown to be associated with negative impacts on fetal and child development. This study aims to address this gap by analyzing the relationships between drinking water access and water and food security with mental well-being amongst prenatal women in low-income, urban neighborhoods of Beira, Mozambique.

Methods: Data for this cross-sectional analysis were collected among pregnant women in their third trimester in Beira, Mozambique from February 2021 through September 2022. Validated, cross-cultural scale measures of mental well-being and household water and food insecurity were administered to gain insight into participants' experienced states of each factor. Drinking water access was categorized as either on-premise (inside the household's compound) or not. We used generalized estimating equations, binary logistic regression, and causal mediation analysis to examine the associations and mediation of factors along the pathway of drinking water access to mental well-being.

Results: Data from 741 pregnant women were included in our analysis. We did not find drinking water access to be associated with mental well-being (OR 1.01; 95%CI 0.73, 1.39), water security (OR 0.86; 95%CI 0.60, 1.25), or food security (OR 1.01; 95%CI 0.70, 1.46). We found evidence that water security (OR 1.42; 95%CI 0.99, 2.04) and food security (OR 2.23; 95%CI 1.50, 3.31) were individually associated with mental well-being. When food insecurity was included in the model with water security and mental well-being, food security had a mediating effect (ACME 0.05; 95%CI 0.02, 0.07; ADE 0.56; 95%CI 0.04, 0.13).

Conclusion: Our findings support growing literature that water and food insecurity impact the population's mental well-being and, therefore, overall health. Further research is needed to confirm causality along these pathways and determine the specific mechanisms through which these interactions take place.

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INTRODUCTION

Lack of access to safe drinking water affects 2 billion people worldwide,[1] a number that is only expected to grow under the increasing influence of climate change.[2] Rapid and accelerating urbanization also contributes to water scarcity, as the rate of population growth in cities is faster than the rate of infrastructure development in most areas. Often, unplanned and overcrowded settlements do not have sufficient water and sanitation infrastructure.[3] About one third of the global urban population is currently facing water scarcity, and this proportion is expected to grow to almost half by 2050.[4]

While inadequate water drinking access is a key driver of infectious disease transmission,[5] growing evidence has also identified linkages between water access and mental health.[6–11] The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[12] Mental well-being is an integral part of overall health, and thus it is necessary to consider its role when determining the impact of water access on overall health and quality of life.

These burdens of household water management and the toll of mental health are not equally distributed; domestic water supply responsibilities—and the corresponding increased mental load—are disproportionately allocated to women and girls.[6,13–22] When clean, piped water is not available at the household in sufficient quantity, householders, predominantly women, may need to sacrifice time, money, energy, and even water quality to secure water from alternate sources.[8,23] Engaging in water gathering activities can increase one's risk for infection and disease, physical injuries, and overall decreased mental well-being.[22–26] For example, in a low-income, urban area of Bolivia, stressful water events were associated with increased negative emotional impacts for household heads, but female household heads had both a higher responsibility for water-related housework and a greater degree of related emotional distress than male household heads.[13,14]

The type of water source is one component of *water insecurity*, defined as “the inability to access and benefit from adequate, reliable and safe water for well-being and a healthy life.”[27] The presence of a piped water source on a household’s premise has been associated with reducing, although not eliminating, household levels of water insecurity.[28] Mental well-being effects of household water insecurity often include increased levels of anxiety, depression, and psychosocial distress, especially in women.[29–32] In an urban setting of Mexico, indications of household water insecurity were associated with increased levels of stress, again, specifically in female-headed households.[33] Thus, reducing household water insecurity through improving drinking water access may serve as a targeted step in reducing adverse well-being.

The relationship between food security and water security is well established.[30] Evidence from 27 sites in low- and middle-income countries suggest that most plausible directionality of the relationship is that water insecurity is a driver of food insecurity.[30] Piped water on-premise was found to be a protective factor for household water security, and the household’s economic savings associated with increased water security was often spent on food.[28] Food insecurity has been associated with adverse mental health indicators such as anxiety, depression, and frequency of negative emotions, independent of water insecurity.[34–37] Associations between food security and mental health outcomes have also been found specifically in pregnant women across many settings.[38–41]

The relationships between drinking water access, water and food security, and mental well-being are complex and intrinsically related to one another. However, a comprehensive and simultaneous study of these relationships in a single setting and using validated, cross-cultural indicators has yet to be published. Quantifying the relationships between drinking water improvements and these non-traditional outcomes and impacts can inform programs and policies that facilitate health equity. This may be particularly important amongst pregnant women as prenatal stress and poor mental well-being has been shown to be associated with negative impacts on fetal and child development.[42–44] Efforts to address mental well-being during pregnancy can be understood as a major preventative intervention for the developing child.

The purpose of this study was to explore the relationships between drinking water access, water and food security, and mental well-being amongst prenatal women in low-income, urban neighborhoods of Beira, Mozambique. The aims were to: (1) quantify the relationship between drinking water access on prenatal mental well-being, (2) quantify the relationship between water and food security and prenatal mental well-being, and (3) assess for potential mediation by water and food security on prenatal mental well-being.

METHODS

We conducted a cross-sectional analysis to evaluate the associations of drinking water access and water and food security with mental well-being amongst prenatal women in Beira, Mozambique. We used data collected from a matched cohort study titled "Pesquisa sobre o Acesso à Água e a Saúde Infantil em Moçambique (PAASIM—Research on Access to Water and Child Health in Mozambique)." The PAASIM Study was designed to assess the health impacts of piped water supply on young children in low-income, urban neighborhoods of Beira, Mozambique; the study protocol contains additional details of the study.[45] Briefly, this prospective matched cohort study follows mother–child dyads from late pregnancy through 12 months of age to examine the impact of water system improvements on acute and chronic health outcomes in children. The study targeted recruitment of 900 pregnant women in the third trimester from low-income urban area of Beira, in an area comprising ~26,300 households.

Study Population

Mozambique is considered a least developed country, and still has progress to be made in terms of having access to basic drinking water sources.[46,47] In urban areas of Mozambique, 88% of the population has access to at least basic services, but only 65% of the urban population has an improved drinking water source on-premise. The proportion of people in the richest wealth quintile that have access to basic drinking water services in urban areas is 1.8 times the proportion of people in the poorest wealth quintile with access to the same level of services, indicating a great wealth gap.[46] Over half of the urban population in Mozambique live in urban slums where these gaps are most evident.[48]

Beira, with an estimated population of 600,000 people is a rapidly growing port city, rendering it highly vulnerable to increasingly frequent cyclones and flooding, a trend driven by to climate change.[49,50] The impoverished, densely populated informal settlements have the most difficulty recovering from these natural disasters, and even further stress is placed on their limited drinking water sources.[51] Projects are underway to improve piped water supply throughout Beira. The PAASIM Study's primary aim is to determine the impact of these water supply improvements on the enteric health of newborn infants in low-income neighborhoods.[45,52]

Data Source

Data for this analysis was gathered from the PAASIM Study's baseline survey data. Structured household surveys (n=900) were conducted at enrollment of pregnant mothers (February 2021 to September 2022). Active recruitment occurred through identification of pregnant women in the 2020 population-based survey, lists of pregnant women visiting local health centers for prenatal care, and study staff visiting under-enrolled sub-neighborhoods throughout the recruitment period.[45] During the enrollment visit, pregnant women were assessed for study eligibility: (1) 18 years or older, (2) in third trimester of pregnancy (at least 27 weeks pregnant), (3) resides in enrolled study cluster, (4) not planning to move within the next 12 months, (5) carrying a singleton birth and (6) consents to take part in the study. The baseline survey was conducted during enrollment if the consenting participant was at least 31 weeks pregnant, otherwise a follow up visit was scheduled to complete the pre-birth survey. In some instances, the child was born before the scheduled baseline visit took place or the pregnancy was lost. For this sub-study, we limited our analysis to those with data collected during a prenatal baseline visit (Figure 1).

Structured household surveys collected information from the prenatal participant participants on individual and household demographics, drinking water access, household water security, household food security, and maternal well-being among other data required for enrollment and evaluation. All surveys with complete relevant data were included (Figure 1).

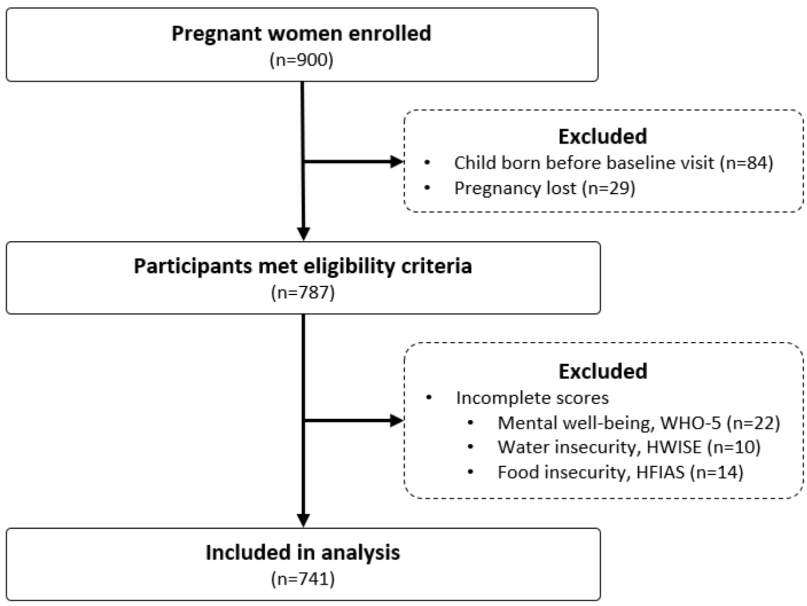

Figure 1. Flow diagram of survey selection based on study eligibility.

Variables

Primary Outcome

Mental Well-Being was assessed using the World Health Organization's WHO-5 Well-being Index,[53] a well-established, globally validated index measure. It uses five non-invasive questions to determine the participant's subjective well-being. Each question asks the participant how often within the past two weeks, ranging from "at no time" (0) to "all of the time" (5), they related to a given statement of positive well-being. Question scores are added together and multiplied by 25. An overall score of 100 indicates the best possible well-being, and a score of 0 indicates the worst possible well-being. This scale score will be assessed as a binary variable, with scores of 50 or less (adverse mental well-being) assigned as 1 in accordance with recent literature.[53]

Predictor Variables

Drinking Water Access for the purpose of this study was defined as the presence of a drinking water source on a household's premise (within the property boundaries of their primary residence and not owned or controlled by neighbors).[54] This measure was derived from indicators outlined by WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP).[55] Respondents provided information on the main source of drinking water for members of the household, location of the drinking water source (i.e., inside or outside of the household's compound). Drinking water access was categorized as a binary variable where 1 indicates no access to a drinking water source is on-premise

Water Security was assessed using the Household Water Insecurity Experiences (HWISE) Scale. The scale was developed and validated to provide a consistent tool for evaluating household water insecurity across different cultural and ecological settings.[27] The scale uses twelve questions that ask the participant how often within the past four weeks, ranging from “never” (0) to “always” (3), they or anyone in their household had a water insecurity experience. An overall score of 36 indicates the highest possible level of water insecurity. This was assessed as a binary variable, where scores at or above 12 indicate water insecurity and are coded as 1.[56] For the remainder of this paper, household water security will be referred to as “water security.”

Food Security was assessed using the Household Food Insecurity Access Scale (HFIAS).[57] The scale uses eight questions to determine how often within the past four weeks they or anyone in their household had a food insecurity experience. The answer scale ranges from “No” (0) to “Often” (3). A score of 27 indicates the highest possible level of food insecurity. For HFIAS, there has not been an established standard cut-off point. However, an HFIAS indicator guide provided conditional equations to determine if the respondent was “food secure”, “mildly insecure”, “moderately insecure”, or “severely insecure.” Upon completing exploratory data analyses comparing continuous versus binary cutoffs of HFIAS, it was determined that the classification of “food secure” and “mildly insecure” as "secure" and “moderately insecure” and “severely insecure” as “insecure” gave the most similar results to HFIAS represented on a continuous scale. Thus, we used binary classification for our analyses where “insecure” is 1. For the remainder of this paper, household food security will be referred to as “food security.”

Moderators were considered in each model as covariates. Because hydrological seasons have a potential to affect water security, seasonality was included as a covariate.[58] The month that the survey was administered in is used to determine the seasonality, with November through April being the hot, rainy season and May through October being the cool, dry season.[59] The primary household wage earner is included as a binary variable, 1 indicating that the participant is the primary wage earner. Wealth score was included as a continuous variable. Respondents answered ten standardized questions from the Simple Poverty Scorecard Poverty-Assessment Tool Mozambique, including questions on household size, materials, assets.[60] Each question’s answer choices correspond with a point total, and points are summed over all ten questions into a poverty score. Age of the prenatal woman was included as a continuous variable and was calculated in years since birth. The number of living children that the participant has was included as a discrete variable. The level of education that the participant received was included as a dichotomous variable, comparing the completion of secondary school and above to some secondary school and below. The impact of preexisting, chronic health conditions and previous infectious diseases were assessed as a binary variable, 1 indicating that one or more relevant condition is present.

The cluster variable of study sub-neighborhood was also included in the created models to account for similarities between participants living in similar geographic areas. The PAASIM Study is comprised of 67 sub-neighborhoods, delineated along natural boundaries such as roads or waterways.[45]

Statistical Analyses

Models were created to determine the relationships between drinking water access, water security, food security, and mental well-being, as displayed in Figure 2, using R version 4.2.2.[61] All models adjusted for the seasonality, SES, age, education completed, and previous diagnosis of an infectious disease, *a priori* selected based on their relevance and univariate relationships to the main predictor and outcome variables (Appendix A).

We assessed if water and food security, represented on continuous scales, were associated with mental well-being score to determine the consistency of the chosen binary cut-off points. The continuous models produced highly similar results to the binary representations (Appendix B & C). We chose to proceed with binary versions of water and food security for homogeneity in statistical estimates (odds ratios), and for cohesion in reporting, looked at the presence of security versus insecurity in these concepts.

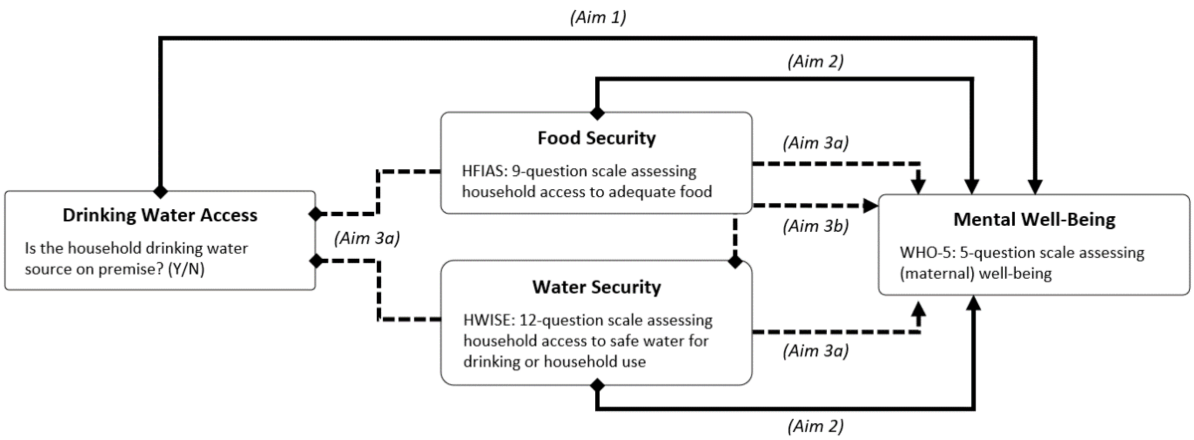

Figure 2. Structural equation model used to evaluate the hypothesized relationships between (aim 1) drinking water access and mental well-being, (aim 2) water and food security and mental well-being, and (aim 3a) potential mediation (mediation indicated by dotted line) of water and food security on the relationship between drinking water access and mental well-being and (aim 3b) potential mediation of food security on the relationship between water security and mental well-being.

For aims 1 and 2, each predictive factor (drinking water access, water security, and food security) was investigated individually for its direct relationship with mental well-being using a binary generalized estimating equations (GEE) framework. The “gee” R package was used to create models with exchangeable correlation structures and robust standard errors.[62] Each GEE model adjusted for sub-neighborhood clustering and reported estimates in the form of odds-ratios with their corresponding confidence intervals and p-values, assessed at the 0.05 significance level.

To ensure suitability for the aim 3 mediation analysis, we first looked at whether significant direct effects were present using binary general linear model (GLM) frameworks. One model was created between the predictor and the outcome and one between the predictor and the mediator. If a direct effect between the predictor and outcome was not present but an effect between the predictor and mediator was present, criteria was met to continue forward with mediation analysis. However, if neither direct effects existed, mediation analysis could not go forward.[63] Based on the individual pathway GLMs, mediation relationships were assessed using the "mediation" R package.[64] The "mediation" package is unfortunately not compatible with GEE functions, so our mediation analyses do not account for clustering. GEE models can be assessed for mediation using the "GEEmediate" R package,[65] however that package uses the difference-in-coefficients mediation analysis method that can only test for presence or absence of a mediated effect. Meanwhile, the "mediation" package uses a causal mediation analysis approach that provides causal effect estimates and is recommended for use in correct interpretation of mediation effects in structural equation models. We therefore chose to proceed with GLM frameworks and the "mediation" package. The significance of the mediation analysis indirect effect was tested with bootstrapping procedures, computing 1000 bootstrapped samples.

RESULTS

Our analysis reflects complete data from 741 prenatal women enrolled in the PAASIM Study (Figure 1 & Table 1). The surveys were conducted in an even distribution between the cool, dry season and the hot, rainy seasons.

Table 1. Descriptive statistics of prenatal participant demographics

Characteristic	**n = 741**[1]
Maternal Age (Years)	
18-25	412 (56%)
26-35	268 (36%)
35+	61 (8.2%)
Number of Currently Living Children	
0	201 (27%)
1	233 (31%)
2	145 (20%)
3	80 (11%)
4+	82 (11%)
Primary Wage Earner	71 (9.6%)
Education Level	
No formal schooling	175 (24%)
Primary completed	402 (54%)
High school completed and above	163 (22%)
Relationship Status	
Married	765(10%)
Not married, living together	531 (72%)
Other	134 (18%)
Home Ownership Status	
Owned	288 (39%)
Rented or leased	367 (50%)
Other	85 (11%)
SES Score (mean, SD)	67.3 (11.8)
Seasonality of Survey Date- Hot, rainy (November-April)	414 (56%)
Previous Diagnosis of Chronic Disease	91 (12%)
Previous Diagnosis of Infectious Disease	399 (54%)

[1]n (%); Mean (SD)

A majority of our participants reported positive well-being and water security; however, a majority also reported not having a drinking water source on-premise and being food insecure (Table 2).

Table 2. Descriptive statistics of key predictors and outcomes

Characteristic	**N = 741**[1]
Positive Mental well-being	471 (64%)
Drinking Water Available on-premise	261 (35%)
HWISE Score (mean, SD)	6.2 (7.9)
Water secure (below 12)	556 (75%)
Water insecure (at or above 12)	185 (25%)
HFIAS Score (mean, SD)	10.2 (6.9)
Food secure (no or mild insecurity)	195 (26%)
Food insecure (moderate or severe insecurity)	546 (74%)

[1]n (%); Mean (SD) [1]n (%); Mean (SD)

We found no evidence of a direct association between drinking water access and mental well-being (Aim 1; OR 1.01; 95%CI 0.73, 1.39; Table 3). We found positive associations between water security and mental well-being (Aim 2; OR 1.42; 95%CI 0.99, 2.04; Table 3) and a positive association between food security and mental well-being (Aim 2; OR 2.23; 95%CI 1.50, 3.31; Table 3).

Table 3. Adjusted associations between drinking water access, water security, and food security and mental well-being

Characteristic	**Positive mental well-being, y=0 (n=471)[1]**	**Adverse mental well-being, y=1 (n=270)[1]**	**OR[2]**	**95% CI[1]**	**p-value**
Drinking water access (no access = 1)	303 (64%)	177 (66%)	1.01	(0.73, 1.39)	0.98
Water Security[3] (insecure = 1)	106 (23%)	79 (29%)	**1.42**	**(0.99, 2.04)**	**0.05**
Food Security[4] (insecure = 1)	324 (69%)	222 (82%)	**2.23**	**(1.50, 3.31)**	**<0.001**

[1]n (%); [2]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level; [3]Water security determined by HWISE score; [4]Food security determined by HFIAS score

We also found no association found between drinking water access and water security (Aim 3a; OR 0.86; 95%CI 0.60, 1.25; Table 4), nor between drinking water access and food security (Aim 3a; OR 1.01; 95%CI 0.70, 1.46; Table 4) (Appendix D). Thus, mediation analysis of the effects of water security and food security on the relationship between drinking water on-premise and mental well-being could not take place.

Table 4. Adjusted associations between drinking water access and water and food security

	Water security[2]			**Food security[3]**		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
Drinking water access (no access = 1)	0.86	(0.60, 1.25)	0.43	1.01	(0.70, 1.46)	0.93

[1]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level; [2]Water security determined by HWISE score; [3]Food security determined by HFIAS score

The effect of water security on mental well-being was determined to be fully mediated by the effects of food security. The total effect of water security on mental well-being (path c) was initially statistically significant (Aim 3b; OR 1.44; 95%CI 1.02, 2.03; Figure 3). We found associations via the indirect effects of water on food security (path a) (Aim 3b; OR 8.38; 95%CI

4.61, 16.85; Figure 3) and food security on mental well-being (path b) (Aim 3b; OR 2.16; 95%CI 1.47, 3.22; Figure 3). When food security was included in the model of the association of water security and mental well-being, the direct effect of water security on mental well-being (path c') became non-significant (Aim 3b; OR 1.19; 95%CI 0.83, 1.70; Figure 3) (Appendix E). Causal mediation analysis further indicates a presence of full mediation as the calculated indirect effects were statistically significant (Aim 3b; ACME 0.05; 95%CI 0.02, 0.07; Table 5), while the direct effects were statistically insignificant (Aim 3b; ADE 0.56; 95%CI 0.04, 0.13; Table 5).

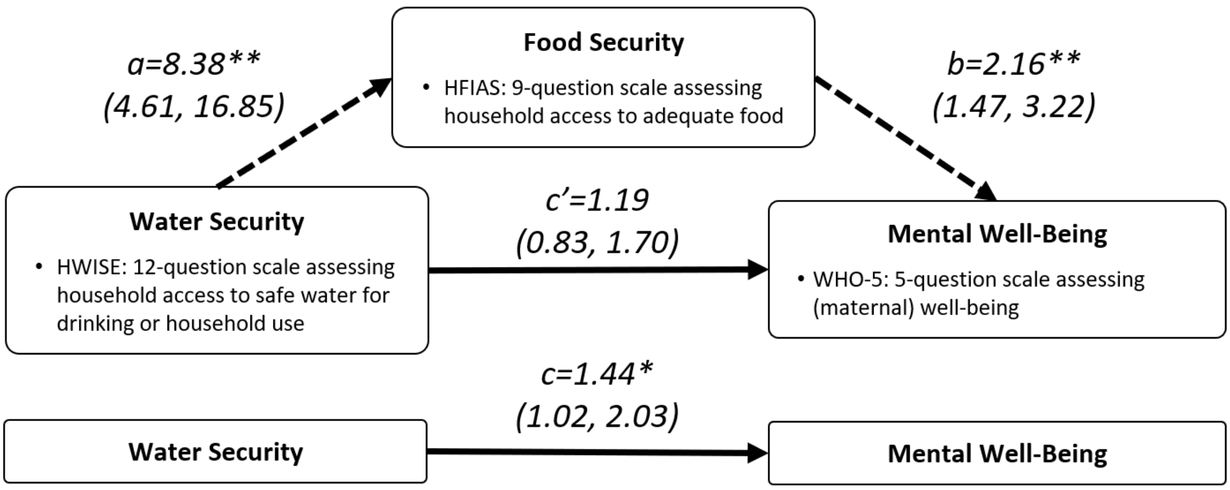

Figure 3. Mediation of food security on the pathway between water security and mental well-being. The figure shows odds ratios with 95% confidence intervals (*p<0.05, **p<0.001).

Table 5. Mediation effects of food security between water security and mental well-being

Mediation Output			
	Estimate[1]	**95% CI**[1]	**p-value**
Average causal mediation effects (ACME)	0.05	(0.02, 0.07)	**<0.001**
Average direct effects (ADE)	0.04	(-0.04, 0.13)	0.32
Proportion Mediated	0.56	(0.15, 2.60)	**<0.04**

[1]Estimate = Increase in probability of outcome, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level

DISCUSSION

Our study investigated the relationships between drinking water access, water and food security, and mental well-being among pregnant women in a low-income, urban area of Mozambique. We did not find evidence of an association between drinking water access on-premise and mental well-being, nor between water access and water and food security, within this population. We did find associations between water and food security and mental well-being both independently and in the form of a mediation pathway.

Though contrary to our initial hypotheses, the lack of association between drinking water access may be related to the relative lack of disparity between levels of drinking water access among our study population. Over 95% of our participants had access to an improved drinking water source within a 30-minute trip. In Kenya, drinking water on-premise yielded a protective association with mental health;[28] however, the site was in a rural village where about 40% of the community used the local lake as their main drinking water source. An initial assessment of satisfaction with water services in our study area revealed no differences in satisfaction based on household water connection status.[66] This research supports the notion that water access is more complex than the proximal location of a drinking water source to one's place of residence. The assessment of "satisfaction" conceptually pairs well with our results that drinking water supply on-premise does not show a significant impact on one's mental well-being.

Water security, an expanded evaluation of the concept of water access, was found to have a relationship with mental well-being. This aligns with the existing literature on impact of water insecurity on stress, anxiety, depression, and other adverse mental well-being indicators.[8,25,29–32] Our findings, however, indicated that this relationship was entirely mitigated, statistically, by the inclusion of food security in the pathway. Previous studies that evaluated the effects of both water and food security with mental well-being found that simply controlling for food security did not eliminate an independent association between water security and mental well-being.[25,31,32,67] A similar mediation relationship to our findings has been established in Haiti, noting that different mental well-being indicators, household water security measurements, and an abbreviated version of the HFIAS scale were used.[7] The authors specifically emphasized that their study would have benefited from a multidimensional and cross-cultural tool for household water security, which our study has accordingly benefited from with the use of the recently validated HWISE scale. Nevertheless, the potential role of water security as an undercurrent among poverty-related stressors, for example food security, and their mental well-being effects emerged.[7] Our findings, coupled with those in Haiti, suggest that food security mediates the effect of water security on mental well-being in certain contexts. However, an in-depth context review may be needed to determine under exactly what circumstances the mediation effects are most prominent.

Our findings of food security's association with mental well-being is consistent with existing literature.[34–40,67–69] Three-quarters of women in our study population reported having moderate or severe food insecurity. This finding is especially acute as our population consisted of pregnant women, over 70% of whom already had other children. The concept of "maternal nutritional buffering" has highlighted that mothers will often reduce their own food intake in order to provide their children with more nutrition in periods of food insecuirty.[70] The subsequent physical consequences of not having adequate nutritional intake are especially severe for pregnant mothers. Potential negative impacts include reduced fetal weight gain, head and abdominal growth, increased fetal distress, abnormalities, and preterm birth, and even increased rates of fetal death.[42–44,71–73] Low birth weight and preterm births are also associated with stunting later in life,[74–76] and stunting has already been identified as a worrying development issue in Mozambique.[77] When determining the overall effects of food insecurity, it is additionally important to consider the potential adverse effects of prenatal mental well-being on fetal growth and development.[42–44] Action plans to prevent adverse fetal and childhood development through improving maternal mental well-being would likely benefit from incorporating strategies to reduce food insecurity among pregnant mothers.[7,78]

Our mediation analysis did not show a direct effect of water security on mental health, but that does not mean interventions to improve water security would fail to impact mental well-being. Indeed, Collins et al. (2019) found that water security impacted food security and subsequentially impacted mental well-being. Their pregnant and post-natal participants discussed that, during the dry seasons when they need to buy water, their money was first spent on water, then on food.[8] In a separate community in Kenya, piped water sources were installed on-premise, and individuals spent money they saved by having this water source on more food.[28] Further understanding of this mediation effect, and the details of the mediation are likely highly context dependent. Additional evidence could help inform which interventions are likely to alleviate food insecurity by accounting for the role water security plays in different communities.

Our findings should be interpreted in the context of the study's limitations. First, our study was cross-sectional, so we were only able to establish associations, not causality. The causal mediation analysis does support causality in the mediation analysis, but it cannot be used to prove causality on its own. Longitudinal studies on these relationships, ideally paired with interventions aimed at reducing water and food insecurity, would give a conclusive understanding to these pathways. Second, our survey relied on self-reported responses to the enumerators. Most often, these surveys occurred outside of a mother’s home in a position visible to neighbors and potentially in earshot. On some occasions, husbands, mothers, and other relatives, friends, or neighbors even sat in on the survey. Thus, participants may have been swayed in their verbal answering of the questions, creating a social desirability bias. Upon discussion with study enumerators on the topic of social desirability bias, they highlighted the trusting and confidential relationships that they formed individually with the participants throughout the course of the study. Though the surveys for this analysis were normally an enumerator's first or second interaction with the participant, the enumerators always presented themselves professionally and perceived that the participants' trust was gained fairly quickly. Third, the study was conducted in a section of a city with a unique context, specifically being a port city that has been subject to many water-related natural disasters recently. Therefore, our findings may not be generalizable to other settings. However, the use of validated scales and controlling for relevant factors, such as socioeconomic status, in turn strengthens the validity of our study's findings.

CONCLUSION

The relationships between drinking water access, water and food security, and mental well-being are complex and intrinsically linked. To our knowledge, this is the first study that evaluates all these relationships in a single context and within pregnant women and in an urban low-income setting. We found that food security has a mediating effect on the relationship between water security and prenatal mental well-being. This case study in low-income, urban Mozambique supports growing literature that water and food insecurity impact the population's overall health, past the physical implications, and these impacts on pregnant women may have generational effects.

APPENDIX

Appendix A:

Characteristic	Univariable analysis w/ DW		Univariable analysis w/ HWISE		Univariable analysis w/ HFIAS		Univariable analysis w/ WHO5	
	Unadjusted OR (95% CI)	p-value	Unadjusted OR (95% CI)	p-value	Unadjusted OR (95% CI)	p-value	Unadjusted OR (95% CI)	p-value
Maternal Age (Years)								
18-25	Reference Level							
26-35	1.2 (0.87, 1.65)	0.26	0.95 (0.88, 1.01)	0.10	0.99 (0.92, 1.06)	0.70	0.77 (0.55, 1.06)	0.11
35+	1.12 (0.63, 1.95)	0.69	1.01 (0.9, 1.13)	0.88	**1.21 (1.08, 1.36)**	**0.00**	**1.85 (1.08, 3.19)**	**0.03**
Number of Currently Living Children								
0	Reference Level							
1	0.88 (0.6, 1.3)	0.53	0.94 (0.87, 1.02)	0.14	0.97 (0.89, 1.06)	0.50	1.02 (0.68, 1.51)	0.94
2	**0.63 (0.4, 0.98)**	**0.04**	0.93 (0.85, 1.02)	0.12	0.96 (0.87, 1.05)	0.35	1.21 (0.78, 1.89)	0.39
3	**0.49 (0.27, 0.87)**	**0.02**	0.93 (0.84, 1.05)	0.23	1 (0.89, 1.12)	0.95	1.18 (0.69, 2.02)	0.54
4+	0.86 (0.5, 1.45)	0.56	0.98 (0.87, 1.09)	0.66	**1.13 (1.01, 1.27)**	**0.03**	1.08 (0.63, 1.84)	0.78
Primary Wage Earner								
No	Reference Level							
Yes	0.75 (0.43, 1.27)	0.30	1.09 (0.98, 1.21)	0.13	1.03 (0.92, 1.14)	0.63	0.94 (0.56, 1.56)	0.82
Education Level								
No formal schooling	Reference Level							
Primary completed	**1.96 (1.29, 3.02)**	**0.00**	1.07 (0.99, 1.15)	0.11	0.95 (0.88, 1.03)	0.18	1.01 (0.7, 1.47)	0.96

High school completed and above	**5.31 (3.31, 8.7)**	**0.00**	1.05 (0.95, 1.15)	0.33	**0.88 (0.8, 0.97)**	**0.01**	0.93 (0.6, 1.46)	0.76
Relationship Status								
Married				Reference Level				
Not married, living together	0.84 (0.51, 1.4)	0.49	**0.75 (0.67, 0.83)**	**0.00**	0.95 (0.86, 1.06)	0.38	0.83 (0.51, 1.37)	0.46
Other	1.21 (0.68, 2.17)	0.53	**0.84 (0.74, 0.94)**	**0.00**	1.06 (0.94, 1.2)	0.34	0.92 (0.52, 1.65)	0.78
Home Ownership Status								
Owned				Reference Level				
Rented or leased	**0.34 (0.24, 0.47)**	**0.00**	1.02 (0.95, 1.09)	0.63	1.06 (0.99, 1.14)	0.08	0.91 (0.66, 1.26)	0.58
Other	0.68 (0.41, 1.11)	0.13	1.01 (0.91, 1.12)	0.89	**1.14 (1.03, 1.27)**	**0.02**	1.01 (0.61, 1.65)	0.98
SES Score	**1.04 (1.03, 1.06)**	**0.00**	1 (1, 1)	0.89	**1 (0.99, 1)**	**0.00**	1 (0.98, 1.01)	0.46
Seasonality of Survey Date								
Hot, rainy (November-April)				Reference Level				
Cool, dry (May-October)	0.88 (0.65, 1.2)	0.42	0.95 (0.9, 1.02)	0.14	1.03 (0.96, 1.1)	0.40	**0.73 (0.54, 0.99)**	**0.04**
Previous Diagnosis of Chronic Disease								
No	Reference Level							
Yes	1.17 (0.74, 1.84)	0.49	0.99 (0.9, 1.09)	0.85	1.03 (0.93, 1.13)	0.62	0.89 (0.55, 1.4)	0.62
Previous Diagnosis of Infectious Disease								
No				Reference Level				
Yes	**1.85 (1.36, 2.53)**	**0.00**	1.04 (0.97, 1.1)	0.28	**1.07 (1.01, 1.14)**	**0.03**	**0.7 (0.52, 0.94)**	**0.02**

Appendix B: Full GEE logistic model using binary scale of Drinking water, HWISE and HFIAS with WHO5 (Aims 1 & 2)

	Drinking Water → WHO5			**HWISE → WHO5**			**HFIAS → WHO5**		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
Drinking water on-premise	1.01	(0.73, 1.39)	0.98	-	-	-	-	-	-
HWISE (binary)	-	-	-	**1.42**	**(0.99, 2.04)**	**0.05**	-	-	-
HFIAS (binary)	-	-	-	-	-	-	**2.23**	**(1.50, 3.31)**	**<0.001**
Survey seasonality (hot, dry = 1)	1.37	(0.99, 1.88)	0.06	1.34	(0.97, 1.85)	0.07	**1.38**	**(1.00, 1.92)**	**0.05**
SES score	1.00	(0.98, 1.01)	0.72	1.00	(0.98, 1.01)	0.71	1.00	(0.99, 1.01)	1.00
Age	1.00	(0.98, 1.03)	0.93	1.00	(0.98, 1.03)	0.90	1.00	(0.97, 1.03)	0.90
Education	0.97	(0.66, 1.42)	0.86	0.97	(0.66, 1.42)	0.87	1.02	(0.69, 1.50)	0.93
Previous diagnosis of infectious disease	**0.69**	**(0.51, 0.95)**	**0.02**	**0.68**	**(0.50, 0.93)**	**0.02**	**0.65**	**(0.47, 0.89)**	**0.008**

[1]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level

Appendix C: Full GEE logistic model using continuous scale of HWISE and HFIAS with WHO5

	HWISE → WHO5			HFIAS → WHO5		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
HWISE	**1.03**	**(1.01, 1.05)**	**0.01**	-	-	-
HFIAS	-	-	-	**1.07**	**(1.04, 1.10)**	**<0.001**
Survey seasonality (hot, dry = 1)	1.34	(0.97, 1.86)	0.08	**1.39**	**(1.00, 1.93)**	**0.05**
SES score	1.00	(0.98, 1.01)	0.70	1.00	(0.99, 1.02)	0.61
Age	1.00	(0.98, 1.03)	0.87	1.00	(0.97, 1.03)	0.93
Education	0.98	(0.67, 1.44)	0.91	1.11	(0.75, 1.63)	0.61
Previous diagnosis of infectious disease	**0.69**	**(0.50, 0.95)**	**0.02**	**0.60**	**(0.43, 0.84)**	**0.003**

[1]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level

Appendix D: Full GLM logistic model of Drinking Water Access with binary HWISE, HFIAS, and WHO5 for assessing mediation suitability (Aim 3a)

	Drinking Water → WHO5			Drinking water → HWISE			Drinking water → HFIAS		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
Drinking water on-premise	1.00	(0.72, 1.40)	>0.99	0.86	(0.60, 1.25)	0.43	1.01	(0.70, 1.46)	0.93
Survey seasonality (hot, dry = 1)	1.34	(0.99, 1.82)	0.06	1.32	(0.94, 1.86)	0.11	0.89	(0.64, 1.25)	0.51
SES score	1.00	(0.98, 1.01)	0.71	1.00	(0.98, 1.01)	0.78	**0.98**	**(0.97, 1.00)**	**0.03**
Age	1.00	(0.98, 1.03)	0.75	0.99	(0.96, 1.02)	0.46	1.02	(0.99, 1.05)	0.18
Education	0.96	(0.65, 1.41)	0.83	0.95	(0.62, 1.45)	0.82	0.72	(0.48, 1.09)	0.12
Previous diagnosis of infectious disease	**0.71**	**(0.53, 0.97)**	**0.03**	1.21	(0.86, 1.70)	0.28	**1.50**	**(1.07, 2.11)**	**0.02**

[1]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level

Appendix E: Full GLM logistic model of binary HWISE with binary HFIAS for assessing mediation (Aim 3b)

	HWISE → WHO5			HWISE → HFIAS			HWISE & HFIAS → WHO5		
Characteristic	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**	**OR[1]**	**95% CI[1]**	**p-value**
Water insecurity (1=insecure)	**1.44**	**(1.02, 2.03)**	**0.04**	**8.38**	**(4.61, 16.8)**	**<0.001**	1.19	(0.83 – 1.70)	0.34
Food insecurity (1=insecure)	-	-	-	-	-	-	**2.16**	**(1.47 – 3.22)**	**<0.001**
Survey seasonality (hot, dry = 1)	1.32	(0.97, 1.79)	0.08	0.81	(0.57, 1.15)	0.2	1.36	(1.00 – 1.86)	0.05
SES score	1.00	(0.98, 1.01)	0.71	0.98	(0.96, 1.00)	0.01	1.00	(0.99 – 1.01)	0.98
Age	1.01	(0.98, 1.03)	0.71	1.03	(0.99, 1.06)	0.11	1.00	(0.98 – 1.03)	0.90
Education	0.96	(0.65, 1.40)	0.83	0.71	(0.47, 1.08)	0.11	1.01	(0.68 – 1.48)	0.98
Previous diagnosis of infectious disease	**0.70**	**(0.52, 0.95)**	**0.02**	**1.49**	**(1.05, 2.12)**	**0.03**	**0.67**	**(0.49 – 0.91)**	**0.01**

[1]OR = Odds Ratio, CI = Confidence Interval, **Bold** indicates statistically significant at 0.05 level

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