

BMJ Open Household determinants of observed handwashing among primary schoolchildren in Hebron, Palestine: a cross-sectional study

Yaman Maani-Abuzahra ^{1,2,3}, Jan Hattendorf,^{1,2} Branwen Nia Owen,^{1,2} Ola Sa'o,⁴ Issa Younan,⁴ Safa Sultan,⁵ Maryna Peter,⁶ Mirko S Winkler,^{1,2} Nicole Probst-Hensch^{1,2}

To cite: Maani-Abuzahra Y, Hattendorf J, Owen BN, *et al*. Household determinants of observed handwashing among primary schoolchildren in Hebron, Palestine: a cross-sectional study. *BMJ Open* 2026;**16**:e103777. doi:10.1136/bmjopen-2025-103777

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<https://doi.org/10.1136/bmjopen-2025-103777>).

Received 15 April 2025
Accepted 26 March 2026



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¹Swiss Tropical and Public Health Institute, Allschwil, Switzerland

²University of Basel, Basel, Switzerland

³An-Najah National University, Nablus, State of Palestine

⁴Cesvi Palestine, Jerusalem, State of Palestine

⁵Palestine Polytechnic University, Hebron, State of Palestine

⁶FHNW University of Applied Sciences and Arts Northwestern Switzerland, Muttenz, Switzerland

Correspondence to

Dr Nicole Probst-Hensch;
nicole.probst@swissthph.ch

ABSTRACT

Objective To assess observed handwashing before eating among primary schoolchildren in a fragile setting in Palestine and examine how this behaviour is associated with household-level and guardian-related determinants.

Design Cross-sectional baseline study embedded within a school-based cluster randomised controlled trial of a hand hygiene intervention. The trial is registered on ClinicalTrials.gov (NCT05964478), and this manuscript reports pre-results baseline findings alongside additional cross-sectional household survey data.

Setting Public primary schools in rural and semiurban areas of the Hebron governorate, Palestine, February–March 2023.

Participants Fifth and sixth grade schoolchildren enrolled in the trial and their co-resident guardians. Children were observed at school and guardians completed a questionnaire at home.

Primary and secondary outcome measures The primary outcome was observed handwashing of both hands with water before eating at school, recorded by trained enumerators during a standardised snack break. Household-level and guardian-level determinants were derived from a structured questionnaire covering five domains: sociodemographic characteristics of guardian and child; household access to handwashing; guardian's health and handwashing knowledge; guardian's self-reported handwashing behaviour; and guardian-reported child handwashing at home. Associations between determinants and observed handwashing were estimated using generalised linear mixed-effects models with school as a random effect; effect modification by whether the responding guardian was the mother was explored.

Results Observation and survey data were available for 931 child–guardian pairs across 26 schools. Overall, 37% of the fifth and sixth grade children were observed washing their hands before eating at school, while 44% of guardians expressed high confidence that their child would do so and 84% exhibited good handwashing knowledge themselves. Poor guardian's self-reported handwashing behaviour was associated with a lower likelihood of children's observed handwashing at school (adjusted OR (OR_{adj}): 0.68; 95% CI 0.47 to 0.99), particularly when the guardian was the mother (OR_{adj}: 0.55; 95% CI 0.40 to 0.90). Household water quality was perceived as poor by

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used direct observation of handwashing behaviour in a real-life school setting, which is considered the gold standard for measuring hygiene practices and reduces the risk of social desirability bias inherent in self-reports.
- ⇒ The study is embedded within a cluster randomised controlled trial, offering a robust sampling design across multiple schools in a fragile setting and enhancing generalisability within the study area.
- ⇒ It uniquely links observed behaviour of children at school with household-level determinants self-reported by guardians, including their knowledge and practices, allowing for a more comprehensive understanding of contextual influences on school-based hygiene.
- ⇒ While we did not frame our analyses around the WHO/UNICEF Joint Monitoring Programme hygiene service ladder, our use of structured observation provides a complementary, behaviour-focused perspective that goes beyond the presence of handwashing facilities to capture what children actually do at a key moment.
- ⇒ The cross-sectional nature of the study limits causal inference, and some variables such as handwashing knowledge were assessed using a small number of items, which may not fully capture the depth of the construct.

95% of guardians. Poor perception was associated with lower likelihood of children washing hands at school (OR_{adj}: 0.41; 95% CI 0.20 to 0.90).

Conclusions In this fragile, water-insecure setting, low levels of observed handwashing before eating and the associations with guardian behaviours and household-level factors suggest that school-based handwashing promotion may be strengthened by complementary strategies that also engage households.

INTRODUCTION

Proper handwashing with soap is one of the most effective interventions to prevent the



transmission of infectious diseases. Handwashing with soap is estimated to reduce risk of diarrhoeal diseases by 30%–48%^{1–4} and respiratory diseases by 21%.^{5,6} It plays a crucial role in controlling the spread of epidemics such as cholera, Ebola, hepatitis E and SARS.^{7–11} The recent COVID-19 pandemic has further highlighted the importance of hand hygiene as improved handwashing practices reduce the likelihood of infection by 36%.¹² In addition, proper handwashing contributes to the fight against antimicrobial resistance.^{13,14}

In humanitarian and fragile settings, where populations face overcrowding, limited access to clean water and poor sanitation, infectious disease transmission is significantly heightened.¹⁵ Faecal-oral diseases, such as diarrhoea, are particularly concerning, accounting for up to 40% of deaths in the acute phase of emergencies.¹⁶ Children are especially vulnerable, and overcrowded schools often act as epicentres of disease transmission.¹⁷

Schools are an important target for the promotion of hand hygiene in humanitarian and fragile settings. Good hand hygiene in schools has been shown to reduce illness-related absenteeism, positively impacting students' educational attainment and long-term well-being.^{18–22} Moreover, children can serve as agents of knowledge transfer, spreading the hygiene practices they learn at school to their households and broader communities.^{23,24}

In humanitarian and fragile settings, challenging school conditions are often paralleled by difficult household environments, leaving children without the foundational knowledge and resources needed to practise proper hand hygiene.²⁵ The promotion of handwashing at the household levels has been shown to reduce infectious disease risk.⁵ As studies often focus on determinants of handwashing behaviours in schools or households separately, there is limited evidence linking these two environments.²⁶ Investigating how household-level determinants influence children's handwashing practices at school is critical for designing effective and sustainable interventions.

The occupied territory of Palestine has been a humanitarian and fragile setting for an extended period. Access to essential services including health, education and water is generally limited.²⁷ The educational system and the school infrastructure depend on humanitarian funding.²⁸ Basic hygiene services are available in only 21% of schools in Palestine.²⁸ Global monitoring of water, sanitation, and hygiene (WASH) is guided by the WHO/UNICEF Joint Monitoring Programme (JMP), which classifies 'basic' hygiene services at schools and in households based on the presence of a handwashing facility with soap and water on premises.²⁸ While this service-level perspective is essential for tracking national and global progress, JMP indicators do not directly capture whether children actually wash their hands at key moments. The present study therefore complements JMP-style monitoring by focusing on objectively observed handwashing behaviour before eating at school and examining how it relates to

household-level determinants in Hebron governorate of the West Bank.

METHODS

Patient and public involvement

This study involved public stakeholders, notably the Ministry of Education (MoE), in school selection, reviewing the study design and data collection tools, and ensuring their cultural appropriateness and feasibility. The Ministry will also play a key role in disseminating findings to local stakeholders, WASH practitioners, non-governmental organisations (NGOs) and study participants.

Additionally, Cesvi Palestine and the Palestinian Polytechnic University contributed to the design and adaptation of data collection tools to ensure suitability and feasibility. They were essential partners during the implementation phase, facilitating collaboration with the MoE and local schools, particularly during the challenging strike conditions.

Study setting and design

The study was conducted across households and schools within four directorates in the Hebron governorate-North Hebron, Hebron, Yatta and South Hebron, located in the southern West Bank, Palestine. Across these four directorates, there are 544 schools and 195 927 schoolchildren.²⁹ The Hebron governorate was selected as a research area due to the collaboration with an NGO, who had successfully collaborated on previous WASH activities with the local authorities. The Hebron governorate is characterised by poor access to safe WASH.

The study is embedded within a school-based cluster randomised controlled trial (cRCT), registered at ClinicalTrials.gov (NCT05964478), aiming to evaluate the effectiveness of a multicomponent intervention on hand hygiene and well-being in schools lacking functional water supply (see Abuzahra *et al*³⁰ for details). The intervention was designed to improve access to basic hygiene services and handwashing behaviour. In this manuscript, we report the baseline pre-results focusing specifically on behavioural outcomes assessed at baseline before the intervention, namely schoolchildren's observed handwashing before eating at school, and on how these behaviours are associated with guardian reported household-level determinants, collected using cross-sectional household survey.

All schoolchildren participating in the intervention study, irrespective of the intervention arm, and their guardians living in the same household were recruited for this cross-sectional substudy, which was conducted at baseline between February and March 2023 before the intervention. The sample size for the number of children in the study was defined by the cRCT's sample size. The required sample size was determined at the cluster (school) level, based on simulations in R conducted for the underlying cluster randomised trial. We assumed an intraclass correlation coefficient of 0.20 for the primary

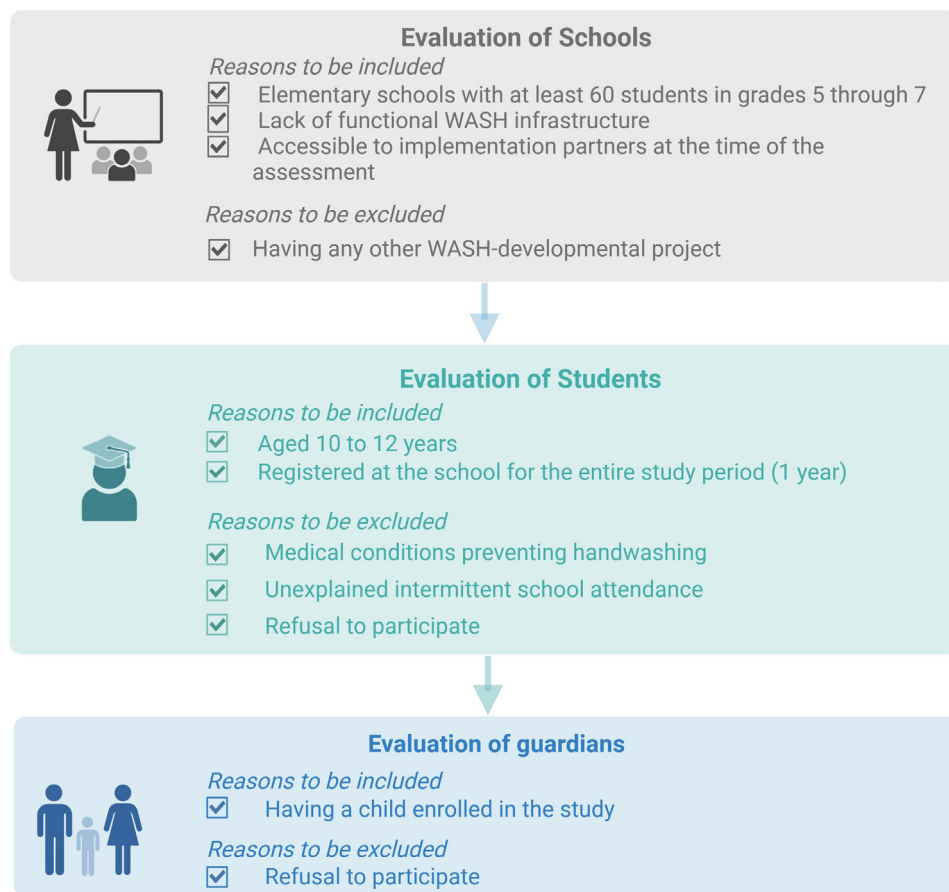


Figure 1 Eligibility criteria for schools, children and guardians. Created with BioRender.com. WASH: water, sanitation and hygiene.

behavioural outcome (handwashing before eating at school), and a prevalence of 20% in control schools vs 45% in intervention schools 1 year after baseline. With 13 schools per arm and 50 children per school (26 schools, 1300 children in total), the trial had at least 80% power at a 5% significance level to detect this difference. For this sub-study, the number of guardians added was equal to the number of children in the sample.

Recruitment and eligibility of schools, children and guardians

Schools for the cRCT were selected using data from the Facility Evaluation Tool for WASH in schools (FACET WINS) conducted by the implementation partners in all public primary schools in the study area, in consultation with the MoE, the Palestinian WASH cluster and UNICEF. Eligible schools met three criteria at the time of the FACET survey: (1) they were deemed accessible to the implementation partners; (2) they lacked functional WASH infrastructure and (3) they had ≤ 60 students enrolled in grades 5–7. ‘Lack of functional WASH infrastructure’ was defined as having an unreliable or absent on-premises water source and/or insufficient functional handwashing and sanitation facilities relative to enrolment (see figure 1 for eligibility criteria of schools).

As part of the selection process of the required sample of 50 schoolchildren from each school, schoolchildren were assessed for eligibility (see figure 1 for eligibility

criteria of schoolchildren). Depending on the class sizes, the 50 eligible children were either randomly selected from a single class or subsequent to the random selection of two classes.

Guardians of the selected children were invited to complete a self-reported questionnaire if they met the eligibility criteria shown in figure 1. Teachers gave the questionnaires to the children, asking them to have one of their guardians fill it out and return it to the school.

The trial protocol, which includes the observation approach, was registered on ClinicalTrials.gov (NCT05964478). Schools and guardians consented to the study participation. The person identifying data and the pseudonymised research data are stored separately on secure servers at Swiss Tropical and Public Health Institute (SwissTPH) with controlled and restricted access for 10 years.

DATA COLLECTION

Primary outcome: observed handwashing behaviour of schoolchildren

The primary outcome was measured through structured observation, which has been identified as the gold standard for assessing handwashing behaviour in school settings and is widely used in school-based hygiene



research.^{31–35} Structured observation allows behaviours to be recorded in real-life contexts and at predefined key moments, providing a direct measure of handwashing practice that complements infrastructure-focused indicators.³⁶ The method is rooted in a careful definition of categories and information that guide the reporting process.³⁷

In the context of the baseline assessment of the cRCT, thus before applying the intervention, children were observed for washing their hands before eating at school. In the cRCT protocol, handwashing before eating at school was prespecified as the primary behavioural endpoint. This moment could be standardised across all participating schools and children, as it occurs during a shared snack break, and allowed observers to record behaviour for all enrolled children within a defined time window. Other key handwashing moments, such as after using the toilet, depend on individual toileting events and would have required substantially longer observation periods or a much larger sample to capture comparable numbers of opportunities across schools. In the context of observing handwashing before eating, all enrolled children were engaged in a painting activity, followed by receiving a snack. Children were observed for washing or not washing both hands before eating the snack.³⁰ To minimise the Hawthorne effect (the tendency of individuals to modify their behaviour due to their awareness they are being observed³⁸), children were not informed of being observed and the data collectors were not getting closer to the children being observed than needed to observe soap use.

The observed handwashing behaviour before eating at school yielded a dichotomous outcome measure: whether or not washing of both hands occurred before eating. Unlike JMP hygiene indicators, which classify service levels based on the availability of a handwashing facility with water and soap, our outcome reflects the observed behaviour of children at a specific, standardised opportunity (before eating) during the school day. Due to the inconsistent availability of soap at schools and the risk that schools might temporarily install soap in response to being observed, we defined handwashing as washing both hands with water, irrespective of whether soap or another handwashing agent was visibly used. Observers recorded contextual notes, including ‘not visible’; or ‘soap or water was not available’.

Potential personal and household-level determinants of schoolchildren’s handwashing behaviour at school

In the context of the cRCT each child was characterised by the class grade, the school attended, the school’s directorate, as well as by sex.

Information on potential household determinants of handwashing behaviour at school was derived from the questionnaire filled in on paper by one of the guardians living in the same household as the enrolled schoolchild (for the questionnaire: see online supplemental table 1). All information on guardians’ own handwashing

practices and on the child’s handwashing behaviour was self-reported by the responding guardian.

Questionnaire items were developed from a literature-based conceptual framework of the personal, physical and social contextual correlates with a potential influence on schoolchildren’s handwashing behaviour. The questionnaire was prepared in English, translated into Arabic, and back-translated into English to check consistency. The MoE reviewed and approved the questionnaire to assure its cultural suitability and sensitivity. The questionnaire domains consisting of five parts are displayed in figure 2. Within this framework, household water and soap conditions were captured through separate questions on water availability, perceived water quality and soap-related practices at household handwashing places, reflecting key contextual constraints in the study setting (see online supplemental table 2).

Data management

For quality assurance and harmonisation of observations across children and schools, the first author trained the observation team on observation techniques, data reporting and ethical considerations using standardised forms. The approach was piloted in test schools before implementation in study schools to ensure feasibility. Observation checklists and guardian questionnaires were completed on paper. At the end of each day, observers reviewed their own forms for completeness and obvious inconsistencies, and the first author and a field supervisor from the implementing NGO checked the collected forms for missing or unclear entries. Data from the paper forms were then entered into a password-protected electronic database. The field supervisor and the first author independently cross-verified the electronic entries against the original paper forms and resolved any discrepancies.

Statistical analyses

We first described sample characteristics and observed handwashing behaviour. We then used univariate and multivariable mixed-effects logistic regression models to examine sociodemographic, structural and behavioural determinants of handwashing.

The final set of variables considered for inclusion in the multivariate regression (online supplemental table 2) were partly a priori selected by expert knowledge, and the conceptual framework presented in figure 2 and thereafter complemented by additional variables selected by statistical significance and model fit using Bayesian Information Criterion. The selection process consisted of the following: First, all variables belonging to a specific questionnaire domain were included in domain-specific regression models. Second, variables that were statistically significantly ($p < 0.05$) associated with handwashing behaviour in domain-specific models were combined into the final multivariate logistic model. Third, to ensure representation of each domain of the conceptual framework, variables with the strongest association and

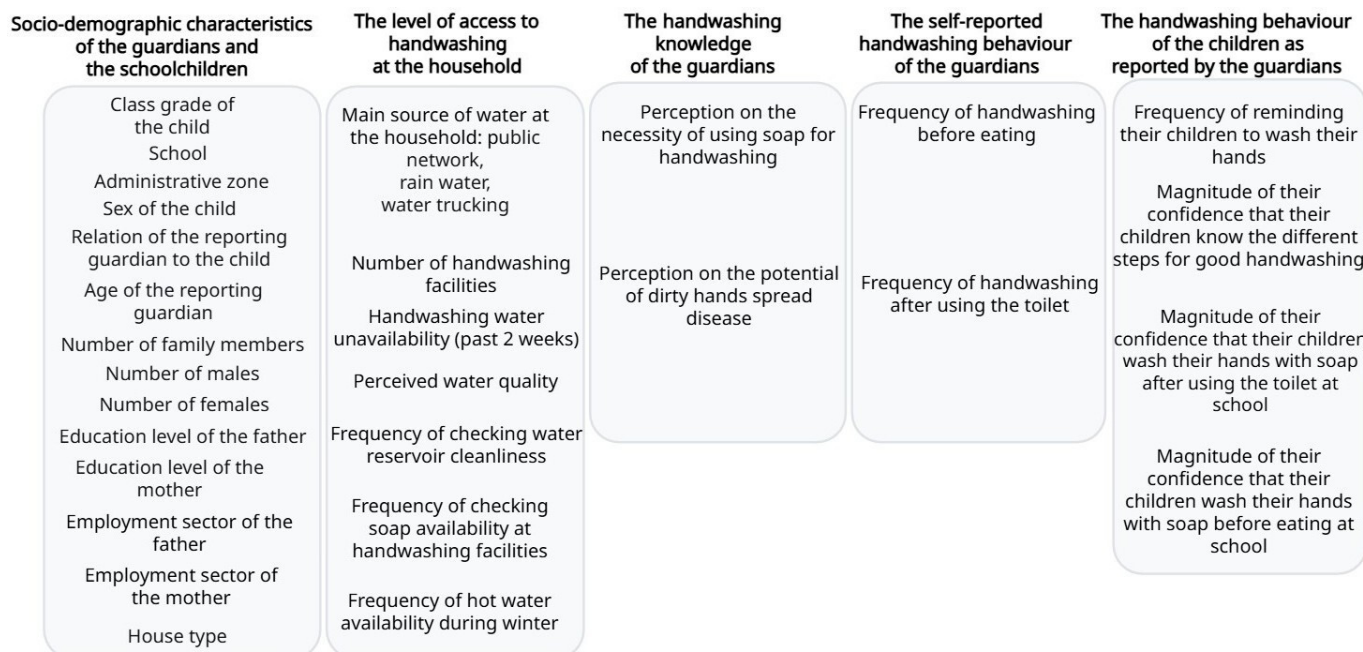


Figure 2 The conceptual framework of the personal and household-level correlates that were examined in the questionnaire answered by the guardians of the schoolchildren enrolled in the study.

with a plausible influence on the child's handwashing behaviour were retained in the final model in the absence of statistical significance (guardian's handwashing knowledge; guardian's confidence in the child's handwashing behaviour).

Variables that remained after this selection process constituted the final parsimonious multivariable mixed-effects logistic regression model and included: (1) sociodemographic characteristics of schoolchildren and guardians (child's sex and class grade; guardian's age and guardian-child relationship); (2) guardian's perceived water quality derived from a composite of reported clarity, colour, and smell of the main household water source; (3) guardian's handwashing knowledge; (4) guardian's self-reported handwashing behaviour and (5) guardian's confidence in the child's ability to wash hands correctly. Full definitions and recoding of variables are provided in online supplemental table 2.

Schools were added to the model as a random effect to account for correlation within schools. Additionally, we tested effect modification by the responding guardian being the child's mother or not and ran stratified models. As sensitivity analysis, we excluded one directorate and one school at a time from the model to assess their influence on the association.

Both the observational data and the questionnaire data were first collected using paper-based forms and then transferred to Open Data Kit Central (V.2023.3.1) on smartphones and tablets for storage and analysis. We conducted all analysis in R V.4.3.2.³⁹ Regression models were fitted using the lme4.⁴⁰

RESULTS

Enrolment

26 schools with 50 eligible schoolchildren from two classes per school formed the basis for this study. Due to prolonged school strikes during data collection, not all planned observations and questionnaires could be completed; ultimately 26 schools were retained in the analysis, with 1135 children observed and 931 guardians returning questionnaires. Because the analyses used mixed-effects logistic regression models that account for clustering at the school level and individual-level variation, the reduction in individual sample size primarily reduced precision but did not compromise the cluster-level power of the study (online supplemental figure 1).

Personal and household-level characteristics

The sociodemographic characteristics of the schoolchildren and their guardians are summarised in table 1. Most participants came from Hebron (39%) and South Hebron (33%). A higher proportion of schoolchildren were female (63%). Nearly two-thirds of the children were in fifth grade (61%), typically aged 10–11 years, while the remainder were in sixth grade. Half of guardian respondents (53%) were between the ages of 31 and 40 years, and the majority were the children's mothers (73%). A third (36%) of the guardians had a university education. In terms of employment, the majority (62%) were classified as 'Other,' likely reflecting the employment status of mothers, who constituted 73% of the respondents and were primarily engaged in household responsibilities.

The distribution of personal and household determinants of guardians is presented in table 2 and online supplemental table 3. Only 38% of households were

Table 1 Sociodemographic characteristics of schoolchildren and their guardians in Hebron governorate, Palestine, gathered through a household survey, February–March 2023

Characteristic	N (%) / mean (SD)
Sociodemographic characteristics	
Directorate	931
North Hebron	114 (12%)
Hebron	359 (39%)
Yatta	153 (16%)
South Hebron	305 (33%)
Sex of the child*	931
Female	583 (63%)
Male	348 (37%)
Class grade of the child*	931
Fifth	564 (61%)
Sixth	367 (39%)
Age of the reporting guardian*	896
≤30	157 (18%)
31–40	476 (53%)
>40	263 (29%)
Relation of the reporting guardian to the child	926
Mother	678 (73%)
Other	248 (27%)
Number of family members (n=931)	7 (2)
Number of male members in the family (n=931)	4 (1)
Number of female members in the family (n=931)	4 (2)
Education level of the reporting guardian (father/mother)	854
School	239 (28%)
High school	305 (35.7%)
University education	236 (36.3%)
Employment sector of the reporting guardian (father/mother)	848
Private	231 (27.2%)
Public	90 (10.6%)
Other	527 (62.1%)
Type of the family house	925
Independent house	580 (63%)
Owned or family housing	301 (33%)
Rented apartment	44 (4.8%)

*Characteristics marked with an asterisk are included in the final multivariate model.
N, number; SD, standard deviation.

connected to the public water network, while nearly half reported rainwater as their main source, and most households (83%) reported that water had been unavailable in the household less than half of the time in the

Table 2 Distribution of personal and household determinants included in the final regression model, Hebron governorate, Palestine, February–March 2023

Characteristic	N (%)
Perceived water quality*	925
Good quality perceived	46 (5.0)
Poor quality perceived	879 (95.0)
Handwashing knowledge†	926
Good	775 (84)
Poor	151 (16)
Handwashing index‡	927
Frequent	588 (63)
Less frequent	339 (37)
Confidence in child's handwashing§	923
Medium or low	303 (33)
High	620 (67)

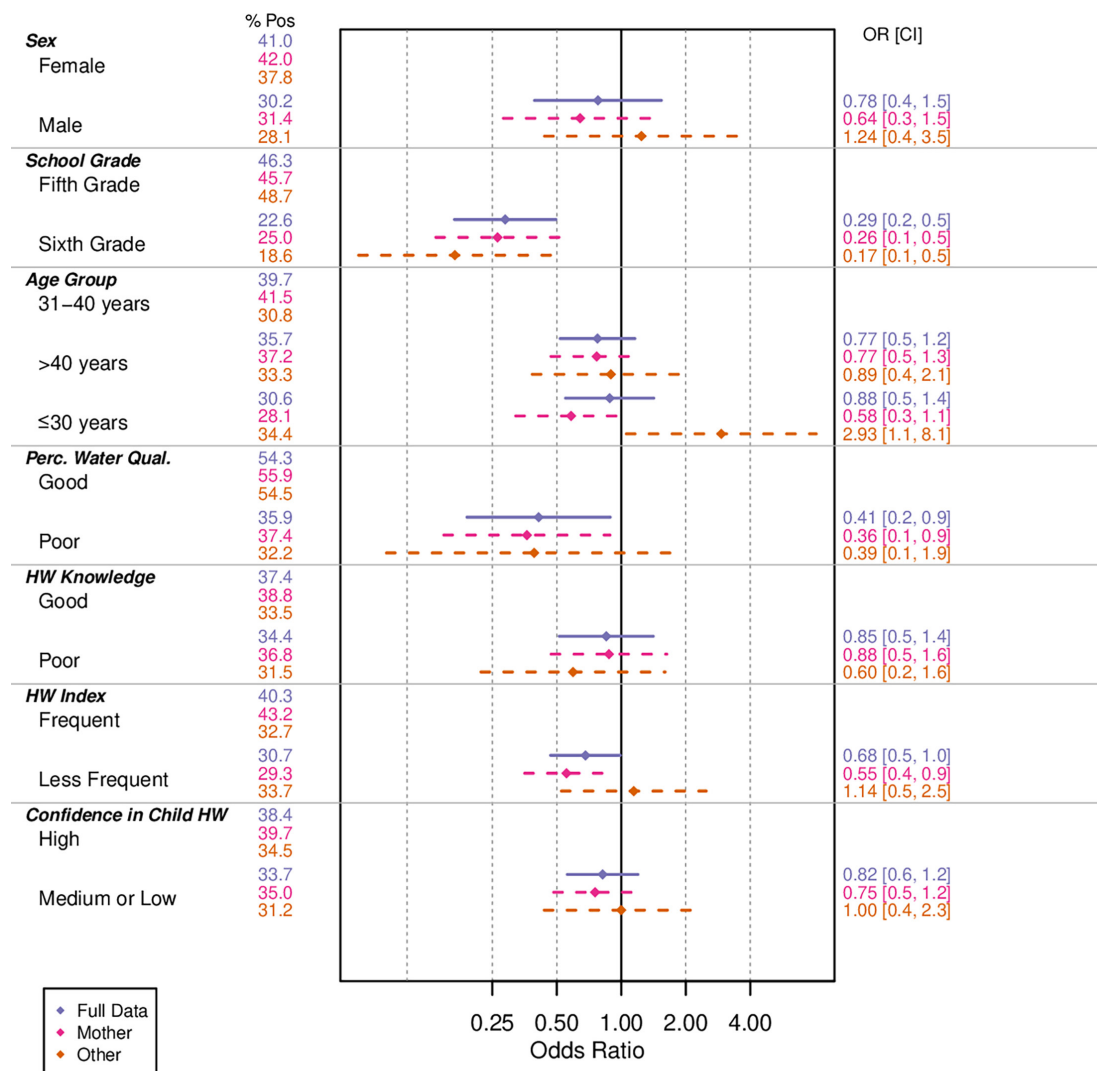
*Perceived water quality: 'good' describing 'colourless, odourless and transparent' water and 'poor' if any of the criteria was not met.
†Handwashing knowledge: index variable (good/poor), created from responses to two questions assessing the perceived necessity of using soap and the perceived potential for dirty hands to spread disease. 'Good' is describing guardians with an understanding of the relevance of using soap and of dirty hands spreading disease.
‡Handwashing index: index variable (frequent/less frequent), developed by combining responses on the frequency of handwashing before eating and after using the toilet. 'Frequent' handwashing describes guardians who wash their hands more than half of the times before eating and after using the toilet.
§Confidence in children's handwashing behaviour: (high/medium or low) confidence of reporting guardian in their child's knowledge of proper handwashing steps derived from a 5-point Likert scale.

preceding 2 weeks (online supplemental table 3). Despite this, perceived water quality was rated as poor by 95% of guardians. The majority (84%) met our definition of good handwashing knowledge, and 63% reported usually washing their own hands both before eating and after using the toilet (handwashing index). Two-thirds (67%) expressed high confidence in their child's ability to wash hands correctly (table 2).

Observed hand hygiene practice and associated factors

Out of the 931 schoolchildren observed, only 37% washed their hands before eating during the observation at school.

The independent associations of determinants with children's handwashing behaviour at school are presented in figure 3, which displays adjusted ORs (aORs) and 95% CIs for the full sample and stratified by whether the respondent was the mother; the same aORs and CIs are also presented in tabular form in online supplemental table 4) (see online supplemental figure 2 for comparison univariate vs multivariate associations in the full sample). The odds of



Proportion (% pos) represents the percentage of students who washed their hands before eating at school
Odds Ratios (OR) and 95% Confidence Intervals (CI) are shown for full data and stratified by mother and other

Figure 3 Multivariate mixed-effect regression models on the independent association of determinants with handwashing (HW) before eating at school among children, showing the full model (N=881; purple), the model for mother respondents (N_{mother}=647; pink) and the model for non-mother respondents (N_{other}=234; orange) in Hebron governorate, Palestine, February–March 2023.

the children’s handwashing before eating at school were about three times lower among sixth graders compared with fifth graders (OR_{adj}: 0.29 (95% CI 0.2 to 0.5)). Similarly, when guardians reported poor perceived water quality, the children were less than half as likely to wash their hands before eating at school (OR_{adj}: 0.41 (95% CI 0.2 to 0.9)). A guardian’s poor handwashing behaviour was associated with a lower likelihood of children washing their hands before eating at school (OR_{adj}: 0.68 (95% CI 0.47 to 0.99)).

Sex of the child, the age of the guardian, guardian’s handwashing knowledge, and guardian’s confidence in their children’s handwashing were not independently associated with the observed handwashing of children at school.

We observed that the respondent being the mother slightly modified the association between guardians’

and children’s handwashing behaviour at school. Only when the mother was the respondent, was an infrequent handwashing behaviour on her side associated with a lower likelihood of the child washing their hands before eating at school (OR_{adj}: 0.55 (95% CI 0.4 to 0.9)). Handwashing behaviour in other respondents was not associated with observed handwashing before eating at school among schoolchildren (OR_{adj}: 1.14 (95% CI 0.5 to 2.5)).

There was a statistically non-significant observation that the guardian being in the youngest age group was only associated with a decreased likelihood of the child washing hands before eating at school if the guardian was the mother.

Sensitivity analyses on model robustness

Sensitivity analyses showed that ORs remained robust to excluding any individual school or any individual



directorate (see online supplemental figure 3 and online supplemental figure 4).

DISCUSSION

To the best of our knowledge, this study is the first to objectively assess handwashing practices among primary schoolchildren in rural and semiurban Palestine. It goes beyond evaluating determinants at school to explore the influence of household-level factors. We found that the majority of children did not wash their hands before eating, but engaging guardians and households harbours the potential to improve this non-compliance in future interventions.

Two out of three children were observed to not wash their hands before eating at school. Many previous school-based studies in fragile settings relied on self-reported handwashing data. These studies from different countries and cultural contexts reported non-compliance rates between 6% and 78%.^{41–52} Self-reports are prone to social desirability bias and may not accurately reflect actual behaviour.^{53 54} In fact, higher non-compliance rates between 66% and 85% were reported in studies on observed handwashing behaviour.^{35 55} The high non-compliance rate with handwashing at school observed in this study is in line with evidence from similar settings and raises concerns about the risk of infection.

The study results suggest that the household environments of schoolchildren may influence their handwashing behaviour at school. Guardians', and in particular mothers' own poor handwashing behaviour, reflected in the self-reported handwashing (HW) index, was associated with a lower likelihood of children washing hands. Previous studies show that children of parents who frequently practice thorough handwashing have higher compliance.⁵⁶ Studies also confirm the important role of the mother. In a study on Iraqi internally displaced persons (IDP) camp, mothers were primary influencers of children's handwashing behaviour.⁵⁷ Similarly, a study in Saudi Arabia found a positive correlation between the mother's education and the schoolchildren's hand hygiene practices.⁵² In our study, the important role of the mother is further supported by the fact that young guardian age had an adverse effect on child's handwashing, particularly if the guardian was the mother. The current and previous evidence support the idea that parental bonding and role modelling significantly impacts children's health-promoting behaviours. Family engagement, including discussions, further boosts handwashing compliance.^{58–63} Therefore, future interventions promoting hygiene practices in schoolchildren may benefit from also targeting the behaviour of their guardians, with a special focus on mothers. Studies should test the benefit of combined interventions

In addition to family engagement, targeted engagement of older students at school seems to be a WASH priority. We found that sixth graders less likely wash hands before eating compared with fifth graders. This contrasts some evidence

suggesting higher compliance among older children.^{44 64–66} However, the compliance with age may not be linear and was observed to decline slightly as children age, but improve again after 14 years.^{67 68} Younger children may receive more supervision, such as teacher reminders.⁴⁴ Older students may deprioritise handwashing due to attitudinal shifts or peer influence, especially in social settings.⁶⁵

Perceived household water quality was associated with children's decreased handwashing compliance. In fact, children of guardians who reported poor water quality were less than half as likely to wash hands before eating at school. This observation is consistent with research on water quality perception and hygiene behaviour.^{69–71} Guardians' perception may influence children's behaviour and perceptions, as guardians who doubt water quality may not emphasise handwashing, considering it ineffective as a result of distrusting the water's cleanliness. The comparative link of perceived water quality and handwashing behaviour remains understudied. Given our findings, interventions aiming to improve both actual water quality and public perceptions of water safety could play an important role in strengthening handwashing compliance among schoolchildren.

The prevalence of water quality perceived as poor was in fact very high (95%), even higher than in comparable fragile and humanitarian settings.^{72–74} Reliance on rainwater collection, often contaminated with dirt or animal waste, likely heightened concerns over water quality. Only 38% of households in the study were connected to the public water network, with nearly half relying on rainwater collection, consistent with data on rural Palestine.⁷⁵ Rainwater harvesting is particularly common in areas like Yatta, Hebron, where limited infrastructure and occupation-related restrictions hinder water access.⁷⁵ In such regions, rainwater provides a critical alternative to unreliable municipal networks, highlighting broader water insecurity issues.⁷⁵ The poor perception of water quality, the lacking access to public water networks, and the fact that only 40% of the households had hot water available more than half of the time in winter—itsself associated with poor hand hygiene during cold periods, point to the critical water situation in Palestine. Maintaining water quality in the fragile and humanitarian settings of Palestine is therefore a public health priority.^{27 76}

Although guardians' own self-reported poor handwashing practice was associated with children's observed poor hand hygiene at school, and despite the critical water situation, respondents demonstrated good handwashing knowledge, understanding the importance of soap and its link to disease prevention. 63% of participants frequently washed hands before eating and after toilet use, a rate consistent with observations in other settings.^{56 62 77–80} 69% of households regularly checked for soap availability at handwashing facilities, indicating a stronger commitment to hygiene compared with other studies.^{54 79} 52% of guardians reminded children to wash hands, 67% believed their children knew proper handwashing steps, and 61% were confident about children's handwashing after toilet use. Interestingly, the fact that only 44% were confident in children's handwashing before meals reflects similar findings from Jordan, Saudi Arabia, Oman

and Ethiopia, where toilet hygiene is emphasised over meal-related hygiene.^{49 52 55 81} The gap between guardians' high confidence and the children's actual handwashing practices suggests that this confidence may reduce parental guidance and monitoring, potentially leading to lower handwashing compliance. The high degree of guardians' hand hygiene knowledge and behaviour point to fertile grounds for WASH interventions in households.

The study's strengths include the objective assessment of children's handwashing behaviour through observation, reducing self-reporting bias. Handwashing opportunity before eating was selected for measurement, as it allowed for an objective and standardised assessment across all participating schoolchildren during the course of the experiment and as endpoint for the current observational study. The study is among the few to examine the association of personal, physical and social household-level factors with handwashing practices at school.

This study has some limitations. First, although the underlying cRCT and baseline survey collected information on WASH infrastructure and access, we did not structure the present analysis around the WHO/UNICEF JMP hygiene service ladder and therefore do not report JMP service levels as outcomes. Instead, our primary outcome was observed handwashing behaviour before eating at school, analysed in relation to household-level determinants including guardians' handwashing behaviour. This behavioural focus provides a complementary perspective to service-level monitoring but limits the direct comparability of our findings with national JMP coverage estimates. Second, we observed only a single handwashing opportunity per child (before eating during one school day) and did not capture other handwashing moments such as after using the toilet. This limited number of observed events restricts our ability to fully characterise children's hand hygiene patterns and may underestimate non-compliance at other critical times. Third, the household-level factors assessed were not exhaustive, and future research should explore additional determinants, potentially using methods beyond self-reporting to assess guardians' behaviours. A comparison of guardians', teachers' and children's objectively assessed handwashing behaviour would be ideal. Fourth, the study did not distinguish between children's handwashing with and without soap, which may inflate estimates relative to the ideal benchmark of handwashing with soap and water. While handwashing with soap is more effective for disease prevention, UNICEF's 2015 *Advancing WASH in School Monitoring* highlights that handwashing with clean water alone, though less ideal, is still better than no handwashing or using contaminated water.⁸² Our decision to focus on handwashing of both hands with water, regardless of soap use, reflects the inconsistent availability of soap at schools and the need for a pragmatic behavioural indicator in this fragile setting. Fifth, the assessment of guardians' hand-hygiene knowledge was based on only two questions and may not capture the full scope of their knowledge. More detailed studies are needed, such as those using comprehensive questionnaires covering techniques, critical moments and hygiene-related diseases.^{54 83} Finally, the

statistical power of the study was limited by its sample size, as evidenced by wide CIs particularly in the subgroup of non-mother guardians.

CONCLUSIONS

The study highlights a substantial gap in handwashing before eating among schoolchildren in a fragile, water-insecure setting of Palestine, and shows that selected household-level factors and guardian behaviours are cross-sectionally associated with children's handwashing at school. These findings suggest that school-based handwashing promotion may be strengthened by complementary strategies that engage households. The high level of households' understanding of the relevance of hand hygiene indicates fertile ground for WASH interventions that integrate the household environment. Randomised studies with intervention arms that target handwashing-related aspects at both school and household are needed to formally test such integrated approaches.

Acknowledgements The authors express their deep gratitude to the Swiss Agency for Development and Cooperation (SDC) for funding and supporting the Hands4Health project (7F-I F-I 0345.03.01), with special thanks to Nathalie Wyzer and Martina Schmidt for their invaluable support. We also extend our sincere appreciation to all the children and their guardians who participated in this research, demonstrating great collaboration despite the challenging circumstances. Special thanks go to the Ministry of Education teams, including the regional directorates, school health departments and school staff (principals and teachers) who facilitated data collection efforts, even amidst the difficulties posed by strikes and logistical challenges. We acknowledge the An-Najah National University for their collaboration in securing ethical approval and their support during implementation, particularly Dr Abdulsalam Al-Khayyat and Dr Hasan Futan for their academic and administrative support, and Nour Al-Qadi and Samar Al-Khalidi for logistical assistance. The authors also extend gratitude to the Cesvi team for supervising the implementation process (OS, IY, Roberto Turcato and Simone Balboni) and to all the data collectors for their dedication and courage in working under challenging conditions (Ahmad Amro, Lama Banat, Shatha Banat, Mutaz Abuzahra and Riham Abu Munshar). We highly appreciate the support of Marco Verber, formerly of the University of Applied Sciences and Arts Northwestern Switzerland, for his technical expertise and project management contributions. Lastly, we thank Palestine Polytechnic University for their support during implementation, particularly Dr Hasan Abusalha, Dr Maher Ja'bari and SS.

Contributors NP-H was the principal scientific lead for this research, overseeing the study design, implementation, data analysis and interpretation. As the main supervisor, NP-H provided critical guidance and ensured the scientific rigour of the study at every stage. YM-A and NP-H conceptualised the research project and managed its administration. YM-A was responsible for the study design, securing ethics approval, supervising fieldwork, coordinating data collection activities, data curation and conducting the formal analysis (with support from JH). MSW was the principal investigator of all impact evaluation research activities within the Hands4Health study. MP and MSW secured funding for the study. MP also managed the overall Hands4Health project. JH was the primary statistical advisor, providing extensive statistical support and data visualisation, with additional contributions from BNO. OS, IY and SS, as focal points of the implementation partner, played a key role in developing the study protocol, supporting all implementation activities and leading coordination with the Ministry of Education, including organising and facilitating data collection. The Ministry of Education (MoE) team (Ahmad Salah, Amjad Hemaidat, Razan Salah and Wissam Nakhleh) contributed to the selection of schools for the study, coordinated project activities within schools, reviewed data collection tools for appropriateness and granted formal approval for their use. They also facilitated school access and collaboration throughout the study. NP-H and MSW supervised YM-A throughout the research. YM-A and NP-H drafted the manuscript. JH, BNO, MSW, MP, OS, IY and SS reviewed and revised the manuscript and approved the final version. Guarantor: NP-H is the guarantor of this work and accepts full responsibility for the integrity of the study, had access to the data and controlled the decision to submit for publication.

Funding This study was funded by Direktion für Entwicklung und Zusammenarbeit (Hands4Health project (7F-I 0345.03.01)).

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was granted by the institutional Review Board of An-Najah National University, Palestine (H. Sp. Feb. 2023/18) and the Ethics Committee for Northwestern and Central Switzerland (Ethikkommission Nordwest- und Zentralschweiz; AO_2023-00047). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The data supporting the findings of this study are available in an anonymised format on reasonable request. Due to ethical and privacy considerations, access to the dataset is restricted to ensure confidentiality. Researchers interested in accessing the data may contact (YM-A or NP-H) at (yaman.abuzahra@swisstph.ch or nicole.probst@swisstph.ch). Requests will be reviewed on a case-by-case basis, and data sharing will be subject to institutional and ethical approvals.

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ORCID iD

Yaman Maani-Abuzahra <https://orcid.org/0009-0005-9541-4621>

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