Zentrum für Entwicklungsforschung (ZEF)

Improving children's environmental health in Metro Manila, Philippines, through a school water, sanitation, and hygiene intervention

Dissertation

zur Erlangung des Grades

Doktorin der Ernährungs- und Lebensmittelwissenschaften (Dr. troph.)

der
Landwirtschaftlichen Fakultät
der
Rheinischen Friedrichs-Wilhelm-Universität Bonn

von

Stephanie Ocampo Sangalang

aus
Manila, Philippinen

Bonn 2023

Referent: Prof. Dr. Thomas Kistemann
Korreferent: Prof. Dr. Christian Borgemeister
Komitteemitglied: Prof. Dr. Ute Noethlings

Tag der mündlichen Prüfung: 15. Februar 2022

Angefertigt mit Genehmigung der Landwirtschaftlichen Fakultät der Universität Bonn

ABSTRACT

Diarrhoea is a leading cause of death and disease globally, while dehydration impairs cognitive performance and malnutrition threatens children's physical growth and neurodevelopment and increases risks for chronic diseases. Especially in the Global South, millions of children are exposed to inadequate water, sanitation, and hygiene (WaSH) in schools, increasing their risk of developing the above diseases. However, it is uncertain which types of school WaSH interventions are most effective in decreasing disease risks. The WaSH in Metro Manila Schools (WMMS) study involved an assessment of the association between school WaSH and children's diarrhoea, malnutrition, and dehydration. It also involved an evaluation of a school WaSH intervention on malnutrition, dehydration, health literacy, and handwashing. The aim of the WMMS study was to promote children's health by protecting children from WaSH-related diseases.

The WMMS study was comprised of two research projects launched in the capital of the Philippines, the megacity known as Metro Manila. During the first project, a cross-sectional study of 1,558 children from 15 public schools was conducted. The WaSH situation in schools was assessed and prevalence rates of diarrhoea, malnutrition, and dehydration were measured. Based on findings, an intervention package was developed to reduce malnutrition and dehydration, and increase health literacy and handwashing. During the second project, a cluster-randomised controlled trial was conducted in the same 15 schools as above. The intervention consisted of health education, WaSH policy workshops, provision of hygiene supplies, and WaSH facilities repairs. Outcomes were: height-for-age (HAZ) and body mass index-for-age Z scores (BAZ); stunting, undernutrition (thinness, severe thinness), overnutrition (overweight, obesity), dehydration prevalence; scores for health literacy-overall and health literacy-related to handwashing; observed handwashing practice. Measurements were: malnutrition status via anthropometry, dehydration via urine specific gravity and urine test strips, health literacy via questionnaire, and handwashing via observation. Mixed logistic and linear regression models were used to analyse changes in outcomes between baseline and endline. Two additional cross-sectional studies were conducted to assess household risk factors and water quality in schools and homes.

The cross-sectional study was conducted between February 2017 and June 2017. Over 28% (421) of students had diarrhoea and 68% (956) were dehydrated. Over 15% (227) of students were stunted, ~9% (127) were undernourished, and >21% (321) were over-nourished. Diarrhoea was associated with poor handwashing, while dehydration was associated with the lack of water in school restrooms. Stunting was linked with not using the school restroom, the lack of water in school restrooms, and the lack of hygiene lessons in school. Risks of diarrhoea, stunting, and undernutrition decreased as the number of school restrooms increased. The cluster-randomised controlled trial was conducted between June 2017 and March 2018. At baseline, 756 children in 15 school clusters were enrolled. 78 children in 2 clusters were purposively assigned to the control group. 678 children in 13 clusters were randomly assigned to one of three intervention groups: low-, medium-, and high-intensity health education. Data on malnutrition and health literacy at eight months were available for 677 and 661 children, respectively (93% of children were measured at eight months). Adherence to the health education component of the intervention was high across all intervention groups. None of the interventions reduced undernutrition prevalence, improved HAZ or BAZ, or improved overall health literacy scores compared to the control.

Low-intensity health education reduced stunting, while high-intensity health education reduced overweight and both low- and high-intensity health education reduced obesity prevalence. Medium- and high-intensity health education reduced severe dehydration prevalence. Medium-intensity health education increased knowledge about using handwashing to prevent infection. High-intensity health education increased knowledge about handwashing with soap. Medium- and high-intensity health education increased observed handwashing after using the toilet/urinal compared to the control.

The Philippines Department of Education implemented policies in 2015 and 2016 to address inadequate school WaSH and promote children's health. Much progress has been made in improving school WaSH. However, during the WMMS study the adequacy of WaSH facilities was found to be low in public schools, and children had insufficient knowledge about WaSH, practiced poor handwashing, and suffered from negative health, nutrition, and hydration outcomes. A comprehensive school-based WaSH intervention, combining interactive health education with WaSH policy workshops, provision of hygiene supplies, and WaSH facilities repairs, did not reduce child undernutrition or improve HAZ, BAZ, or overall health literacy. However, increasing the intensity of health education reduced prevalence of stunting, overnutrition, and severe dehydration, while increasing health literacy related to handwashing and handwashing practice. The mixed nature of this evidence is consistent with findings from previous studies, demonstrating that managing school WaSH and improving children's health is complex. This study concludes that comprehensive school WaSH interventions should be refined and further investigated as they have the potential, not only to improve learning environments, but also to prevent disease in learners. While improved health and education outcomes directly benefit individuals, long-term investment in effective school WaSH interventions may be capable of benefiting entire communities, with implications especially for countries in the Global South.

VERBESSERUNG DER UMWELTGESUNDHEIT VON KINDERN IN METRO MANILA, PHILIPPINEN, DURCH DURCH MAßNAHMEN HINSICHTLICH WASSERQUALITÄT SOWIE SANITÄR- UND HYGIENEBEDINGUNGEN IN SCHULEN

KURZFASSUNG

Durchfall ist weltweit eine der häufigsten Todes- und Krankheitsursachen, während Dehydrierung die kognitiven Leistungen beeinträchtigt und Unterernährung das körperliche Wachstum und die neurologische Entwicklung von Kindern gefährdet und das Risiko chronischer Krankheiten erhöht. Vor allem im globalen Süden sind Millionen von Kindern in Schulen unzureichenden Wasser-, Sanitär- und Hygienebedingungen ausgesetzt, was ihr Risiko, an den genannten Krankheiten zu erkranken, erhöht. Es ist jedoch ungewiss, welche Arten von WaSH-Maßnahmen in Schulen das Krankheitsrisiko am wirksamsten verringern. Im Rahmen der Studie WaSH in Metro Manila Schools (WMMS) wurde der Zusammenhang zwischen schulischem WaSH und Durchfall, Unterernährung und Dehydrierung bei Kindern untersucht. Außerdem wurde eine schulische WaSH-Intervention in Bezug auf Unterernährung, Dehydrierung, Gesundheitskompetenz und Händewaschen bewertet. Ziel der WMMS-Studie war es, die Gesundheit von Kindern zu fördern, indem sie vor WaSH-bedingten Krankheiten geschützt werden.

Die WMMS-Studie bestand aus zwei Forschungsprojekten, die in der philippinischen Hauptstadt Metro Manila, einer Megastadt, durchgeführt wurden. Im Rahmen des ersten Projekts wurde eine Querschnittsstudie mit 1.558 Kindern aus 15 öffentlichen Schulen durchgeführt. Die WaSH-Situation in den Schulen wurde bewertet und die Prävalenzraten von Durchfall, Unterernährung und Dehydrierung wurden gemessen. Auf der Grundlage der Ergebnisse wurde ein Interventionspaket zur Verringerung von Unterernährung und Dehydrierung sowie zur Verbesserung der Gesundheitskompetenz und des Händewaschens entwickelt. Im Rahmen des zweiten Projekts wurde in denselben 15 Schulen wie oben beschrieben eine randomisierte kontrollierte Studie durchgeführt. Die Intervention umfasste Gesundheitserziehung, WaSH-Workshops, die Bereitstellung von Hygieneartikeln und die Reparatur von WaSH-Einrichtungen. Die Ergebnisse waren: altersbezogene Körpergröße (HAZ) und altersbezogener Body-Mass-Index (BAZ); Stunting, Unterernährung (Dünnheit, starke Dünnheit), Überernährung (Übergewicht, Fettleibigkeit), Verbreitung von Dehydrierung; Werte für Gesundheitskompetenz insgesamt und Gesundheitskompetenz in Bezug auf Händewaschen; beobachtete Händewaschpraxis. Gemessen wurde der Status der Unterernährung mittels Anthropometrie, die Dehydratation mittels spezifischem Uringewicht und Urinteststreifen, die Gesundheitskompetenz mittels Fragebogen und das Händewaschen mittels Beobachtung. Gemischte logistische und lineare Regressionsmodelle wurden verwendet, um die Veränderungen der Ergebnisse zwischen dem Ausgangswert und dem Endwert zu analysieren. Zwei zusätzliche Querschnittsstudien wurden durchgeführt, um die Risikofaktoren in den Haushalten und die Wasserqualität in Schulen und Haushalten zu bewerten.

Die Querschnittsstudie wurde zwischen Februar 2017 und Juni 2017 durchgeführt. Über 28 % (421) der Schüler hatten Durchfall und 68 % (956) waren dehydriert. Über 15 % (227) der Schüler waren unterentwickelt, ~9 % (127) waren unterernährt und >21 % (321) waren überernährt. Durchfall wurde mit schlechtem Händewaschen in Verbindung gebracht,

während Dehydrierung mit dem Mangel an Wasser in den Schultoiletten zusammenhing. Verkümmerung wurde mit der Nichtbenutzung der Schultoiletten, dem Mangel an Wasser in den Schultoiletten und dem fehlenden Hygieneunterricht in der Schule in Verbindung gebracht. Das Risiko von Durchfall, Stunting und Unterernährung nahm ab, je mehr Schultoiletten vorhanden waren. Die cluster-randomisierte kontrollierte Studie wurde zwischen Juni 2017 und März 2018 durchgeführt. Zu Beginn der Studie wurden 756 Kinder in 15 Schulclustern eingeschrieben. 78 Kinder in 2 Clustern wurden nach dem Zufallsprinzip der Kontrollgruppe zugewiesen. 678 Kinder in 13 Clustern wurden nach dem Zufallsprinzip einer der drei Interventionsgruppen zugewiesen: niedrige, mittlere und hohe Intensität der Gesundheitserziehung. Daten zur Unterernährung und zur Gesundheitskompetenz nach acht Monaten lagen für 677 bzw. 661 Kinder vor (93 % der Kinder wurden nach acht Monaten gemessen). Die Teilnahme an der Gesundheitserziehung war in allen Interventionsgruppen hoch. Keine der Interventionen führte zu einer Verringerung der Unterernährungsprävalenz, einer Verbesserung der HAZ oder BAZ oder einer Verbesserung der allgemeinen Gesundheitskompetenz im Vergleich zur Kontrollgruppe. Eine niedrige Intensität der Gesundheitserziehung reduzierte die Unterernährung, während eine hohe Intensität der Gesundheitserziehung das Übergewicht reduzierte und sowohl die niedrige als auch die hohe Intensität der Gesundheitserziehung die Prävalenz der Adipositas verringerte. Mittlere und hohe Intensität der Gesundheitserziehung verringerte die Prävalenz von schwerer Dehydrierung. Mittlere Intensität der Gesundheitserziehung steigerte das Wissen über das Händewaschen zur Infektionsprävention. Hochintensive Gesundheitserziehung steigerte das Wissen über das Händewaschen mit Seife. Mittel- und hochintensive Gesundheitserziehung steigerte die Häufigkeit des Händewaschens nach der Benutzung der Toilette/des Waschbeckens im Vergleich zur Kontrollgruppe.

Das philippinische Bildungsministerium hat 2015 und 2016 Maßnahmen ergriffen, um gegen unzureichende WaSH in Schulen vorzugehen und die Gesundheit der Kinder zu fördern. Bei der Verbesserung des WaSH in Schulen wurden große Fortschritte erzielt. Im Rahmen der WMMS-Studie wurde jedoch festgestellt, dass die WaSH-Einrichtungen in öffentlichen Schulen unzureichend sind, die Kinder nur unzureichend über WaSH Bescheid wissen, sich schlecht die Hände waschen und unter negativen Auswirkungen auf Gesundheit, Ernährung und Flüssigkeitszufuhr leiden. Eine umfassende schulbasierte WaSH-Intervention, die interaktive Gesundheitserziehung mit WaSH-Politik-Workshops, der Bereitstellung von Hygieneartikeln und der Reparatur von WaSH-Einrichtungen kombinierte, führte weder zu einer Verringerung der Unterernährung von Kindern noch zu einer Verbesserung der HAZ, BAZ oder der allgemeinen Gesundheitskompetenz. Eine Erhöhung der Intensität der Gesundheitserziehung verringerte jedoch die Prävalenz von Unterernährung, Überernährung und schwerer Dehydrierung und erhöhte gleichzeitig die Gesundheitskompetenz in Bezug auf das Händewaschen und die Praxis des Händewaschens. Die gemischten Ergebnisse stimmen mit den Erkenntnissen früherer Studien überein und zeigen, dass das Management von WaSH in Schulen und die Verbesserung der Gesundheit von Kindern komplex sind. Diese Studie kommt zu dem Schluss, dass umfassende WaSH-Maßnahmen an Schulen verfeinert und weiter untersucht werden sollten, da sie das Potenzial haben, nicht nur das Lernumfeld zu verbessern, sondern auch Krankheiten bei den Lernenden zu verhindern. Während verbesserte Gesundheits- und Bildungsergebnisse direkt dem Einzelnen zugute kommen, können langfristige Investitionen in wirksame schulische WaSH-Maßnahmen möglicherweise ganzen Gemeinschaften zugute kommen, was insbesondere für Länder im globalen Süden von Bedeutung ist.

DEDICATION

I dedicate this work to God, through whom all things are possible! I also dedicate this work to: my parents, Augusto Borja Sangalang and Gertrudes Ocampo Sangalang, for their love; my brother, Adrian, for his encouragement; my Sisters in Christ, the Crusaders of Mary, for their prayerful support.

The woman said to Him, "Sir, you do not even have a bucket and the well is deep; where then can you get this living water?" (John 4: 11).

TABLE OF CONTENTS

ABBREVIATIONS

BAZ	body mass index-for-age Z-score
BMI	body mass index
CDC	Centers for Disease Control and Prevention
CI	confidence interval
cm	centimeter
CONSORT	CONsolidated Standards Of Reporting Trials
COVID-19	Coronavirus disease 2019
DALY	disability-adjusted life-year
DepEd	Department of Education Philippines
DOH	Department of Health Philippines
DRKS	German Clinical Trials Registry
E.coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
FAO	Food and Agriculture Organization
GDP	gross domestic product
GLMM	generalized linear mixed model
GPS	global positioning system
HAZ	height-for-age Z-score
ID	identification (number)
Inc.	incorporation (business)
IQR	interquartile range
KAP	knowledge, attitudes, and practices
kg	kilogram
LMIC	low and middle income countries
m	meter
mg	milligram
MOOE	Maintenance and Other Operation Expenses
N/A	not applicable
OR	odds ratio

RCT	randomized controlled trial
RR	relative risk
SD	standard deviation
SDG	Sustainable Development Goals
SE	standard error
SES	socioeconomic status
sg	specific gravity (of urine)
SOP	standard operating procedure
STH	soil-transmitted helminth
UN	United Nations
U.S.A.	United States of America
USD	United States Dollar
WaSH	water, sanitation, and hygiene
WHO	World Health Organization
ZEF	Center for Development Research (German: Zentrum fuer Entwicklungsforschung)

LIST OF TABLES

Note: The letter 'S' indicates that the table is in the Supplementary Materials of the given publication. If a table has multiple pages, then only the first page is listed. The numbering of some tables in this dissertation may be different from the numbering used in the published manuscripts (please see dissertation chapters 2-4).

LIST OF FIGURES

Note: The letter ‘S’ indicates that the figure is in the Supplementary Materials of the given publication. If a figure has multiple pages, then only the first page is listed. The numbering of some figures in this dissertation may be different from the numbering used in the published manuscripts (please see dissertation chapters 2-4).

1 GENERAL INTRODUCTION

Inadequate water, sanitation, and hygiene (WaSH) is a condition of the environment that is characterized by inaccessible, insufficient, or unsafe water and/or waste management systems. Examples of environments include homes, schools, and health care facilities. WaSH supplies include water, soap, toilet paper, and paper or towels for drying one's hands after handwashing (HW). WaSH facilities include toilets, urinals, and HW basins. WaSH facilities are characterized as "improved" if they meet the standards of the World Health Organization (WHO) (Table 1.1) (WHO/UNICEF 2021).

Table 1.1: Improved v. unimproved sanitation.

	Improved	**Unimproved**
Drinking water	Piped supplies, e.g.: tap water in the dwelling, yard or plot, including piped to a neighbor, public taps or standpipes, non-piped supplies, boreholes/tubewells, protected wells and springs, rainwater, packaged water, including bottled water and sachet water, delivered water, including tanker trucks and small carts/tanks/drums, water kiosks.	Non-piped supplies, e.g. unprotected wells and springs.
Sanitation	Ensures hygienic separation of human excreta from human contact. Examples: flush / pour flush toilets connected to sewers or latrines connected to septic tanks / pits, on-site sanitation, ventilated improved pit (VIP) latrines, pit latrines with slabs (made of durable, cleanable materials), and composting toilets such as latrines with slabs and container-based systems.	Does not ensure hygienic separation of human excreta from human contact. Examples: networked sanitation wherein flush / pour flush toilets flush to open drain or local environment; on-site sanitation wherein pit latrines lack slabs or platforms, or there are open pits, hanging latrines, and bucket latrines or other unsealed containers.

Inadequate WaSH costs society billions of dollars annually. Direct costs come from medical treatment of WaSH-related diseases like diarrhea, helminth infection, and malnutrition. Indirect costs come from school dropout, decreased education attainment, underemployment with lower income, absence from work, unemployment, and decreased income tax. Inadequate WaSH slows economic growth, hinders development, and perpetuates poverty (Adair et al. 2013). In China alone, diarrhea cost society USD $926.4 million (Jin et al. 2011). Malnutrition, in all its forms, costs society ~USD $3.5 trillion, or 5% of the global gross domestic product (GDP), annually (FAO 2013).

About 25% and 50% of the world's population lack safe drinking water at home and safe sanitation, respectively (WHO/UNICEF 2021). People living in the Global South are disproportionately affected by inadequate WaSH (WHO/UNICEF 2021). The greatest proportion of people exposed to unimproved drinking water sources and unimproved sanitation live in Sub-Saharan Africa (WHO/UNICEF 2021). In 2020 37% of people living in the least developed countries (LDCs) had access to safely managed drinking water, in comparison to 96% of people living in Europe and North America (WHO/UNICEF 2021). About 1/3 of people living in the LDCs were exposed to unimproved sanitation, in comparison to only 2% of people living in Europe and North America (WHO/UNICEF 2021). About 2/3 of people from urban areas have access to basic hygiene, compared to 37% of people from rural areas (WHO/UNICEF 2021).

Inadequate WaSH is a social justice issue because it exacerbates inequalities that affect vulnerable populations. One example is the inequality of access to wastewater treatment between people from high-income (99%) vs low-income (22%) countries (WHO/UNICEF 2021). Another example are the inequalities between people from "fragile" and nonfragile contexts. Fragile contexts are those experienced by migrants, internally displaced persons, and refugees (WHO/UNICEF 2021). Access to basic drinking water and basic sanitation in fragile contexts was 74% and 48%, respectively (WHO/UNICEF 2021). In contrast, access to the same resources in nonfragile contexts were 95% and 87%, respectively (WHO/UNICEF 2021). Access to household toilets/latrines in refugee camps varies across countries, from 100% coverage in Iraq and Mozambique to 2% and 8% in Rwanda and Bangladesh, respectively (WHO/UNICEF 2021).

Ultimately WaSH is a human rights issue because all people, regardless of culture, citizenship, education, or income, are entitled to water and its essential, life-giving and health-promoting benefits. This entitlement has been recognized by international organizations and various policy instruments (Table 1.2).

Table 1.2: Policies defining water as a human right.

<table>
<tr><th>Right to water</th><th>Right to sanitation</th></tr>
<tr><td>United Nations (UN) General Assembly and the Human Rights Council (UN 2010): The right to water entitles everyone to have access to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use.</td><td>UN General Assembly (UN 2015): The right to sanitation entitles everyone to have physical and affordable access to sanitation, in all spheres of life, that is safe, hygienic, secure, and socially and culturally acceptable and that provides privacy and ensures dignity.</td></tr>
<tr><td colspan="2">Terminology (UN-Water undated)</td></tr>
<tr><td colspan="2">
Sufficient: The water supply for each person must be sufficient and continuous for personal and domestic uses. These uses ordinarily include drinking, personal sanitation, washing of clothes, food preparation, personal and household hygiene.
Safe: The water required for each personal or domestic use must be safe, therefore free from micro-organisms, chemical substances and radiological hazards that constitute a threat to a person’s health. Measures of drinking-water safety are usually defined by national and/or local standards for drinking-water quality.
Acceptable: Water should be of an acceptable color, odor and taste for each personal or domestic use. All water facilities and services must be culturally appropriate and sensitive to gender, lifecycle and privacy requirements.
Physically accessible: Everyone has the right to a water and sanitation service that is physically accessible within, or in the immediate vicinity of the household, educational institution, workplace or health institution.
Affordable: Water, and water facilities and services, must be affordable for all.
</td></tr>
</table>

1.1 Health consequences of inadequate WaSH

Acute diseases associated with inadequate WaSH include communicable diseases and acute infections such as cholera, diarrhoea, helminth infection, hepatitis A, malaria, polio, and typhoid. Non-communicable diseases (NCDs) and chronic diseases associated with inadequate WaSH include malnutrition--in all its forms, e.g. stunting, undernutrition, overnutrition--and its possible sequelae, e.g. delayed growth and impaired cognitive development.

WaSH-related diseases are transmitted by pathogens such as bacteria, vectors, and viruses. Transmission occurs via the fecal-oral route. The ‘F’ Diagram illustrates disease transmission pathways (Figure 1.1).

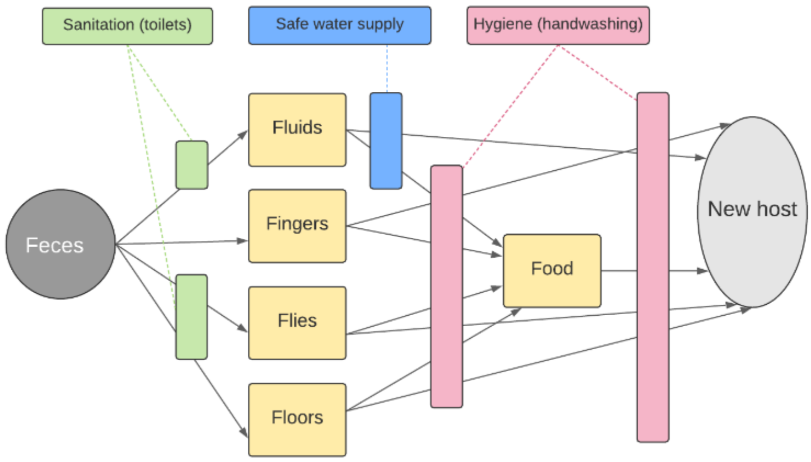


Figure 1.1 'F' Diagram based on Wagner and Lanoix (1958).

1.1.1 Diarrhoea

Diarrhoea is a gastrointestinal disease that is caused by ingestion of bacteria (e.g. *Escherichia coli* [*E.coli*]), parasites (e.g. Giardia), and viruses (e.g. Rotavirus). It occurs when we ingest contaminated food or fluids, as well as putting fingers, contaminated with faeces, inside one's mouth. Diarrhoea is characterized by having ≥ 3 loose stools in one day (WHO 2017a).

While diarrhea is an acute disease, it can have long-lasting effects in people who experience multiple or persistent episodes of diarrhea. Consequences include malabsorption, loss of appetite, and weight loss. These are predisposing factors of various forms of malnutrition, including vitamin deficiency and stunted growth, and can cause impaired cognitive development. For example, lower cognitive ability in schoolchildren has been associated with being malnourished during preschool (Liu et al. 2003).

Diarrhea affects ~2.4 billion people annually (GBD 2016 Diarrhoeal Disease Collaborators 2018). It kills almost half a million children < 5 years old annually (GBD 2016 Diarrhoeal Disease Collaborators 2018). In 2016, diarrhea cost 74.4 million disability-adjusted life-years (DALYs) (GBD 2016 Diarrhoeal Disease Collaborators 2018). These high costs negatively impact low- and middle-income countries (LMICs). For example, in 2018 the cost of treating diarrhea in Bangladesh was $79 million (Hasan et al. 2021).

1.1.2 Malnutrition

Malnutrition is a chronic disease that is classified as stunting, undernutrition, or overnutrition. It is characterized by an imbalance between energy consumption and energy expenditure. Stunting occurs when one's linear growth (i.e. height) is prevented from fully occurring due to a lack of nutrients, vitamins, and minerals. Undernutrition occurs when energy expenditure exceeds energy consumption, causing weight loss. Forms of undernutrition are: thinness, wasting, micronutrient deficiencies, and protein-energy malnutrition (PEM). Overnutrition occurs when energy consumption exceeds energy expenditure, causing weight gain. Overweight and obesity are forms of overnutrition.

The WHO (WHO) (2015; undated) defines malnutrition according to height-for-age Z scores (HAZ) and body mass index-for-age Z scores (Table 1.3).

Table 1.3: Definitions of malnutrition.

Type of malnutrition	**Definition**
Stunting	HAZ < -2
Severe thinness	BAZ < -3
Thinness	-3 < BAZ < -2
Overweight	1 < BAZ < 2
Obesity	BAZ > 2

Note: body mass index-for-age Z score (BAZ); height-for-age Z score (BAZ).

Malnutrition affects about 1 out of 3 people globally (WHO 2017b). In 2018, ~22% (149 million) of all children < 5 were stunted, while 7.3% (49.5 million) were wasted and 5.9% (40.1 million) were over-nourished (Development Initiatives Poverty Research 2020). In 2011, undernutrition caused 45% of all child deaths (Black et al. 2013); overnutrition caused ~7% of deaths (4 million) (GBD 2016 Causes of Death Collaborators 2017). While the prevalence of childhood and adolescent (age 5 - 19 years old) underweight has decreased from in males and females from 2000 to 2016 (Development Initiatives Poverty Research 2020), inequality still exists between income levels. For example, underweight prevalence is up to three times higher in LMICs compared to upper-middle- and high-income countries (Development

Initiatives Poverty Research 2020). High overnutrition prevalence was previously a public health problem mostly in developed countries but it is now increasing in LMICs. Inequality in overnutrition prevalence, among 5 - 19 year-olds, exists between males and females in many LMICs. The widest sex gaps, wherein prevalence in females exceeded that in males, were found in southern and eastern Africa (Development Initiatives Poverty Research 2020).

Individuals, families, and countries experience the “double burden” of malnutrition where multiple forms of malnutrition coexist at all levels of the population. Specifically, this occurs when undernutrition coexists with overweight or obesity (WHO 2017b). At the individual-level, a child may have a micronutrient deficiency while being overweight. At the family-level, a child < 5 may be stunted while his/her mother has anemia. At the country-level, children and adults may simultaneously experience undernutrition and overweight/obesity. An example of assessing the double burden of malnutrition is as follows: measuring the prevalence of childhood stunting (< 5 years), anemia among women of reproductive age (15–49 years old), and overweight (including obesity) in adult women (≥ 18 years old). A 2020 survey found that 124 of 194 countries had high prevalence rates of all three forms of malnutrition (Development Initiatives Poverty Research 2020). Most (30%, 37) of these countries were in Africa (Development Initiatives Poverty Research 2020). A wide range of factors influence the double burden of malnutrition

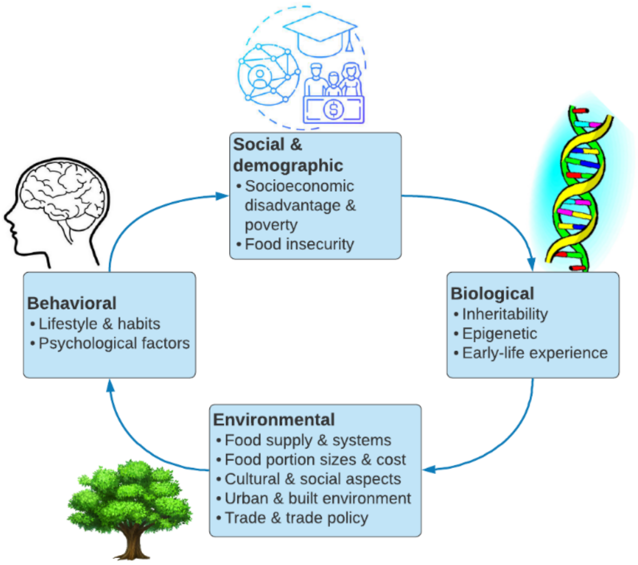


Figure 1.2: Risk factors of the double burden of malnutrition (WHO 2017b).

Macro-level causes of malnutrition are: high food prices, decreased agricultural productivity, ineffective governance, inadequate health services, sociopolitical factors like war, and global warming. Food insecurity, a major risk factor of malnutrition, affected ~1 in 3 people (2.37 billion) in 2020 (FAO, IFAD, UNICEF, WFP, & WHO 2021). Micro-level causes of malnutrition are: poverty, inadequate WaSH, lack of education, behaviors like poor HW, and unhealthy dietary and food preparation practices. Certain diseases increase the risk of malnutrition. Examples of acute diseases are gastroenteritis, diarrhea, and helminth infection. Examples of chronic diseases are HIV/AIDS, Crohn's disease, and celiac disease.

Health consequences of malnutrition include decreased immune function and increased risks of infectious and non-communicable diseases (NCDs). Examples of infectious diseases include bacterial gastroenteritis, viral lower respiratory tract infections, and tuberculosis (Ibrahim et al. 2017) while examples of NCDs include scurvy due to ascorbic acid (i.e. vitamin C) deficiency and rickets due to vitamin D. Malnutrition impedes cognitive development, especially when it occurs during the first 1000 days of life. Household food insecurity has been associated with decreased math and vocabulary skills in children (de Oliveira et al. 2020). Malnutrition's negative effects on cognitive development may persist into adulthood (Waber et al. 2014) and may not be reversible. Some negative effects may extend to future generations (Waber et al. 2018), perpetuating the cycle of poverty. Negative effects include poor socioeconomic outcomes in adulthood (Galler et al. 2012). This is problematic, not only for individuals but for also entire communities and countries, especially those with developing economies.

Malnutrition costs society ~USD $3.5 trillion, or 5% of the global gross domestic product (GDP), annually (FAO 2013). Examples of direct costs include those associated with medical care and examples of indirect costs include those associated with school absence and dropout, underemployment, work absence, unemployment, reduced income, and decreased tax revenue.

1.1.3 Dehydration

Dehydration is a state of water deficit and may involve no salt loss (hypertonic dehydration) or salt loss (isotonic dehydration) (Lacey et al. 2019). The former occurs after insufficient drinking or excessive sweating, while the latter occurs after consuming diuretics or experiencing secretory diarrhoea (Lacey et al. 2019). Water loss at 1% - 3% of body weight may cause thirst and dry mouth, while water loss at 5% - 6% may cause decreased concentration, sleepiness, and tingling/numbness at one's extremities (Grandjean 2005). Water loss at 7% of body weight may cause loss of consciousness, while water loss at 10% of body weight can be fatal (Adolf 1947).

Dehydration can be diagnosed objectively by urine specific gravity (U_{sg}) and observations of dry, cracked lips, and color changes in urine, and subjectively by reports of thirst. Treatment involves water replacement via oral or intravenous fluids.

Dehydration caused 518,000 hospitalizations in the United States in 2004 amounting to over $5.5 billion USD in healthcare costs (Kim 2007). While symptoms of mild dehydration, e.g. dry mouth, headache, may not be bothersome, moderate and severe dehydration can cause dizziness, lethargy, and tachycardia. Acute dehydration can cause seizures and become a medical emergency. Dehydration can also cause cognitive impairments, e.g. decreased concentration and memory. This is problematic especially for school-age children (Bar-David et al. 2005).

1.2 School-based WaSH and nutrition interventions

WaSH and nutrition interventions aimed at children in schools have the advantage of targeting vulnerable populations of young people, during a time of physical growth and cognitive development, in a location where they are gathered for prolonged periods of time. WaSH interventions may have various objectives, from improving school environments to educating schoolchildren. Such objectives are supported by policy instruments at the international and national levels (Table 1.4). But there is a common aim: to promote children's health and prevent disease, so, that school absences may be decreased and learning may be enhanced. For many children, especially in LMICs, education is a critical pathway that can help them escape poverty and its associated consequences, including premature death.

The costs of school WaSH interventions depend on intervention type and duration. Environmental modification, e.g. constructing additional restrooms, are expensive because of materials, labor, and long-term operation and maintenance. Health education, e.g. HW lessons, are inexpensive because they require few material resources and can be incorporated into school curriculum and delivered by teachers.

Regardless of the school WaSH intervention type, it is common practice to combine multiple strategies and involve diverse stakeholder groups, rather than focus only on children. This demonstrates an appropriate understanding about the complexity of WaSH and the need for sustainable behavior change. Constructing additional toilets would not be helpful in decreasing open defection (and ultimately preventing diarrhea) if children do not accept and actually use the toilets as a preferable alternative to the grass field or playground.

Benefits of school WaSH interventions include improved health outcomes, e.g. decreased risk of diarrhea, respiratory infection, and decreased school absence (Trinies et al. 2016).

Table 1.4 Examples of policies at the international and national levels that are relevant to WaSH in schools.

Organization	**Policy goals and guidelines**
United Nations (UN 2017)	Sustainable Development Goal (SDG) 6, Ensure access to water and sanitation for all. Targets: 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all. 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
Philippines Department of Education (DepEd 2016)	Policy and Guidelines for the Comprehensive Water, Sanitation and Hygiene in Schools (WinS) Program. Targets: 1. Water: All schools shall have an organized system to make adequate and safe drinking water as well as clean water for handwashing, toilet use, menstrual hygiene management, and cleaning purposes available to all students during school hours; 2. Sanitation: All schools shall have adequate, clean, functional, safe, and accessible toilet facilities that meet the pupil-to-bowl ratio as stipulated in the Philippine Sanitation Code; maintain cleanliness and safety in and the immediate vicinity of school premises through school-based solid waste management, proper drainage, and the elimination of all possible breeding grounds for mosquitoes to

	prevent vector-borne diseases; and ensure safety in food handling and preparation; 3. Hygiene: All students in school shall perform supervised daily group handwashing with soap and tooth brushing with fluoride, while a system and support mechanisms for effective menstrual hygiene management shall be ensured in all schools; 4. Health Education: All teachers, heads of schools, facilities coordinators, and health personnel shall be oriented on the DepEd WinS program. Trained teachers can conduct Health Education in coordination with community leaders during Parent-Teacher Association (PTA) meetings. All pupils/students shall have a higher awareness of correct hygiene and sanitation practices and develop positive health behaviors; 5. Deworming: At least 85% of all students shall be dewormed semi-annually; 6. Capacity Building: All DepEd WinS program implementers shall undergo orientation on the program as needed.

1.2.1 Hardware

In low-resource settings, such as public schools in LMICs, the quantity and quality of WaSH facilities may be inadequate. In other words, there may be too few toilets for the number of users, toilets may be damaged, and HW basins may lack water. Other problems include toilets that are located too far away from classrooms or toilets that are not accessible for people with limited mobility (e.g. wheelchair users).

Proper operation and maintenance of WaSH facilities like toilets, urinals, and HW basins has been associated with improved satisfaction from the perspective of users such as schoolchildren and teachers (Buxton et al. 2019). This is an important achievement because children who perceive school WaSH facilities to be user-friendly and satisfactory are more likely to use the toilet rather than practice open defecation or postpone defection, which could cause constipation or other intestinal injuries. Furthermore, children who use schools' HW basins may be less likely to ingest or transmit diarrhea-causing pathogens. In contrast, children who have negative perceptions about school WaSH facilities (due to facilities' bad physical appearance, bad smells, and their own feelings on insecurity) are more likely to avoid urinating and defecating in school (Lundblad and Hellström 2005), putting them at risk for urinary tract or intestinal illnesses.

Other interventions based on environmental modification include provision of drinking water and hygiene supplies like soap, toilet paper, towels, and menstruation pads.

1.2.2 Software

In some populations, differences in hygiene-related behaviours may be influenced by social norms, cultural beliefs, and/or lack of knowledge. Different school curricula may exclude lessons about proper HW and avoiding open urination and defecation.

Provision of health education has been associated with improved knowledge about HW (Kim and Choi 2010), infectious disease prevention (Mahmoodabad et al. 2008), and menstruation hygiene (Nagaraj and Konapur 2016). This is an important achievement because increased knowledge can help children identify and possible avoid health threats in their environment. But does increased knowledge affect decision-making and actually lead to behavior change?

Recent school WaSH interventions have been developed to specifically target children's behavior through group dynamics and subtle messaging placed. Group HW and tooth-brushing programs are examples of interventions that rely on the power of role modelling by peers to change behavior. Group HW has been associated with decreased soil-transmitted helminth (STH) infection prevalence (Monse et al. 2013) and group tooth-brushing has been associated with decreased numbers of decayed, missing and filled permanent teeth (Duijster et al. 2017).

Environmental "nudges" are eye-catching symbols that are hung on classroom walls or painted on floors to gently remind children to practice a specific hygiene-related behavior, e.g. HW after eating lunch. Evidence of the effectiveness of environmental nudges has been encouraging. For example, a study of schoolchildren in Bangladesh reported that environmental nudges increased handwashing with soap (Dreibelbis et al. 2016). Another study of schoolchildren in Bangladesh reported that nudge-based interventions were as effective as high-intensity education interventions in handwashing with soap after using the toilet (Grover et al. 2018).

The rationale for implementing behavior modification-based interventions are to empower children to make healthy decisions, to help them develop healthy habits, and to help them sustain positive changes into adulthood.

1.2.3 Health literacy

Health literacy (HL) is "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Institute of Medicine 2004). HL is influenced by education, SES, current health status, and experience with healthcare systems and providers. HL involves competency, self-efficacy, and empowerment. HL is associated with increased disease-specific knowledge and understanding when to seek medical advice or care (Yamaguchi et al. 2020), timely disease screening (Pagán et al. 2012), and health-related quality of life (Wang et al. 2017). Consequences of low HL include increased incidence of missed treatments/therapy appointment, emergency department visits, shorter hospitalization stays, and hospitalizations due to disease complications (Green et al. 2013).

Hygiene-related HL is an individual's ability to understand concepts and use resources to prevent diseases associated with inadequate WaSH. For example, someone who understands infectious disease transmission can wash their hands after using the toilet and before eating to avoid spreading bacteria or viruses that cause diarrhea. School WaSH interventions that incorporate health education with the aim of improving knowledge, attitudes, and practices (KAP), i.e. HL, have been associated with increased reductions in helminth infection prevalence and increased egg reduction rates (Hürlimann et al. 2018).

1.2.4 Handwashing promotion

Proper HW is a key component of any WaSH intervention because it interrupts disease transmission, prevents infection spread, and helps maintain health. HW promotion must take into account HW determinants, including facilitators and barriers of hygiene-related behaviour (Table 1.4).

Table 1.5 HW determinants adapted from the Behaviour Centred Design (BCD) framework (Aunger and Curtis 2016) as cited in (White et al. 2020).

Source of motivation	Types of motivation	Definition
Brain	Executive	Knowledge affects decision to practice HW
	Motivated	Goal affects decision to practice HW; e.g. disgust, affiliation, nurture

	Reactive	Habit affects decision to practice HW
	Discounts	Perceived time, effort, costs needed to practice HW compared to alternatives
Body	Characteristics	Socio-demographic factors, e.g. gender, wealth, age, education, employment
	Senses	Sensory perceptions
	Capabilities	Skills and perceptions about being able and willing to practice HW
Behavior settings	Stage	Design and set up of the HW area
	Infrastructure	Water supply systems, sanitation, kitchen facilities, handwashing facilities
	Props	Value, characteristics, usability, ownership, accessibility of soap and other objects used for HW
	Roles	How one's identity or responsibilities influence his/her HW practices
	Routine	Sequence of behaviors regularly performed with HW
	Norms	Perception of normative setting-specific rules, e.g. descriptive, personal, injunctive, and subjective norms
Environment	Physical	Built environment including climate, geography
	Biological	Factors associated with one's interaction within his/her biological environment
	Social	How one interacts with and perceives social environment and those around them
External context	Political & historical	How culture, politics, policies affect HW

HW prevalence rates vary across population according to income. Observed HW prevalence in Africa and Southeast Asia was 14% and 17%, respectively (Freeman et al. 2014). These rates are below the global average of 19% (Freeman et al. 2014). Observed HW prevalence in high-income countries in the Americas was 49%, but only 16% in low-income countries in the Americas (Freeman et al. 2014). Observed HW prevalence in high-income countries in Europe was 44%, but only 15% in low-income countries in Europe (Freeman et al. 2014).

HW promotion in schools in LMICs has been a top research priority to support public health and development. Proper HW in schools has been associated with decreased school absence (Mintz et al. 2007), including school absence due to diarrhea (Talaat et al. 2011).

The importance of HW was recently raised during the Corona Disease 2019 (COVID-19) pandemic. Proper HW was associated with decreased COVID-19 risk (Beale et al. 2021) and prevalence (Ahmed and Yunus 2020). A cross-sectional study of high school students in Ghana reported that poor HW was associated with not knowing that COVID-19 could be deadly (Apanga et al. 2020). To better protect vulnerable populations in LMICs against the next pandemic, urgent action is needed to increase proper HW.

1.3 Scope of the dissertation

The dissertation describes the research undertaken as part of the WaSH in Manila Schools Project (WMSP), whose primary aim was to improve children's environmental health in the Philippines. The WMSP involved field research in Metro Manila, Philippines, from January 2017 to February 2019. Research activities included multiple cross-sectional surveys and a cluster-randomized controlled trial (cRCT). The cRCT was an originally designed experiment that involved developing, implementing, and evaluating a school WaSH intervention. The WMSP Research Team was multidisciplinary and comprised of a rotating group of five to six research associates, all of whom were Filipino university students or recent graduates. The WMSP timeline and Research Team profile are found in the Appendix 8.1.

Recognizing the complexity of WaSH management in schools, a transdisciplinary approach was applied to mixed research methods. Focus was placed on research questions and hypotheses (Table 1.6) designed to increase understanding about children's environmental health and school Wash.

Table 1.6: Research questions and hypotheses explored in dissertation.

Research questions	Hypotheses
1. How is school WaSH associated with WaSH-related diseases? 1.1 What is the adequacy of WaSH in schools in Metro Manila, Philippines?	It is hypothesized that: school WaSH is strongly associated with WaSH-related disease; WaSH in Manila schools is inadequate; a large proportion of

1.2 What proportion of children have WaSH-related diseases: diarrhea, malnutrition, and dehydration? 1.3 What are the risk factors of children's WaSH-related diseases?	children in Manila are malnourished and dehydration, and a smaller proportion have diarrhea; risk factors of WaSH-related disease include avoiding to use the toilet and now practicing proper HW.
2. Is the school WaSH intervention effective in improving malnutrition, dehydration, HL, and HW? 2.1 Which outcomes can be measured to evaluate the intervention's effects? 2.2 How did the intervention affect outcomes? 2.3 Could the intervention be scaled up for future school WaSH programs?	It is hypothesized that: the school WaSH intervention is effective in improving malnutrition, dehydration, HL, and HW; outcomes can include height-for-age Z scores (HAZ), body mass index-for-age Z scores (BAZ), prevalence of malnutrition, dehydration, and HW, and HL score; the intervention will positively affect outcomes; the intervention can be scaled up.

1.3.1 Research aim and objectives

The research aimed to improve children's environmental health by answering research questions 1 and 2. A variety of scientific approaches were used to answer these questions (Table 1.7).

Table 1.7: Research objectives, methods, and outcomes of the WaSH in Metro Manila Schools Study.

Objectives	Methods	Outcomes
To assess the adequacy of school WaSH; to measure children's nutrition status and prevalence of diarrhea and dehydration; to assess WaSH-related policies and perceptions.	Cross-sectional school survey: interviews, questionnaires, inspections, anthropometry, urine specific gravity	School-level • WaSH policies • Adequacy of school WaSH facilities Child-level • Diarrhea • Malnutrition • Dehydration • Perceptions of WaSH • WaSH-related practices (e.g. toilet use, HW) • Hunger • Food security
To assess the adequacy of home WaSH and family's WaSH-related knowledge and	Cross-sectional household survey: interviews, inspections	• Adequacy of home WaSH facilities • WaSH-related practices (e.g. HW) • Food security

practices and food security.		
To assess the impacts of a school WaSH intervention on children's malnutrition, dehydration, HL, HW; to assess impacts of said intervention on schools' WaSH adequacy.	Cluster-randomized controlled trial: interviews, questionnaires, inspections, anthropometry, urine specific gravity, HW observations	School-level • WaSH policies • Adequacy of school WaSH facilities Child-level • Malnutrition • Dehydration • HL • HW
To assess water quality, including fecal contamination, in schools and homes.	Cross-sectional water quality survey: water sampling, microbiological analyses	Fecal contamination • Coliform • *E.coli* Other indicators • *Temperature* • *Biological oxygen demand* • *Dissolved oxygen* • *Nitrate* • *pH* • *Total dissolved solids* • *Turbidity*
To assess children's overall health status, extreme hunger, perceptions about school WaSH; to assess family's demographic characteristics, SES, food and water security, mode of transportation.	Cross-sectional demographic survey: questionnaire	Household-level • Demographics • SES • Food and water security • Mode of transportation Child level • Overall (self-reported) health status • Experience of severe hunger • Satisfaction with school WaSH • Perception of cleanliness of school WaSH facilities

Note: Escherichia coli (E.coli); handwashing (HW); health literacy (HL); water, sanitation, and hygiene (WaSH).

1.3.2 Structure of the dissertation

The dissertation begins with a General Introduction, describing the context of WaSH in schools, the background of health outcomes explored by the researcher, the research aim and objectives, and the background of the study area and population. Chapter 2 is a publication about the cross-sectional study that assessed school WaSH and prevalence of children's diarrhoea, malnutrition, dehydration, as well as WaSH-related perceptions and practices. Chapter 3 is a publication outlining the study protocol used to conduct a cluster-randomized controlled trial (cRCT) to test the effectiveness of a school WaSH intervention in improving malnutrition, dehydration, HL, and HW. Supplementary Materials include data collection tools, training documents, and intervention materials. Chapter 4 is a publication reporting the results of the cRCT and evidence-based recommendations. Chapter 5 is a General Discussion, which synthesizes the lessons learned from the cross-sectional studies and cRCT, as well as identifies implications for practice, policy, and future research. Chapter 6 is the Conclusion, which describes the outlook for school WaSH and outlines possible next steps. The Appendices contain additional materials from the research.

2 DIARRHEA, MALNUTRITION, AND DEHYDRATION ASSOCIATED WITH SCHOOL WATER, SANITATION, AND HYGIENE IN METRO MANILA, PHILIPPINES: A CROSS-SECTIONAL STUDY

This chapter has been published as Sangalang et al. (2022) *Science of the Total Environment 838*(2); https://doi.org/10.1016/j.scitotenv.2022.155882.

ABSTRACT

Introduction: Diarrhoea, malnutrition, and dehydration threaten the lives of millions of children globally due to inadequate water, sanitation, and hygiene (WaSH). Our study aimed to identify environmental and behavioural risk factors of these health outcomes among schoolchildren in Metro Manila, Philippines.

Materials and methods: We analysed data from a multistage cluster sample of schoolchildren in grades 5, 6, 7, 9, and 10 (ages ~10-15 years old) to investigate WaSH facilities and hygiene practices. Outcomes were: self-reported diarrhoea, measured via questionnaire; observed malnutrition (stunting, undernutrition [underweight/thin and wasted/severely thin], over-nutrition [overweight and obese]), measured via anthropometry; dehydration, measured via urine specific gravity/urine test strips. We used multiple logistic regression to explore correlates.

Results: We included 1,558 students from 15 schools in three cities. Over 28% (421) of students had diarrhoea and 68% (956) were dehydrated. Over 15% (227) of students were stunted, ~9% (127) were undernourished, and > 21% (321) were over-nourished. Diarrhoea was associated with poor handwashing, while dehydration was associated with the lack of water in school restrooms. Stunting was linked with not using the school restroom, the lack of water in school restrooms, and the lack of hygiene lessons in school. Undernutrition was associated with the lack of a school restroom cleaning policy. Risks of diarrhoea, stunting, and undernutrition decreased as the number of school restrooms increased. Risks of stunting and overnutrition decreased as the numbers of school toilets increased. Having more than seven handwashing basins was associated with decreased risk of dehydration.

Discussion: Findings from our cross-sectional study cannot describe causation. We have found associations that suggest that school restroom cleaning policies, adequate water supply, improved handwashing, and hygiene education are needed to prevent disease. School-based WaSH interventions are recommended to provide water in school WaSH facilities, promote handwashing, and improve hygiene-related knowledge.

Key words: dehydration, diarrhoea, nutrition, paediatrics, water quality

2.1 Introduction

Diarrhoea affects 2.39 billion people globally and caused 1,655,944 deaths in 2016 (Troeger et al., 2018). In the same year, about 60% of diarrhoea deaths (829,000) were attributed to inadequate water, sanitation, and hygiene (WaSH) (Prüss-Ustün et al., 2019). Nearly 90% of deaths occurred in South Asia and sub-Saharan Africa (Naghavi & et al., 2017). People of low socioeconomic status (SES) are disproportionately affected due to their high exposure to risk factors like inadequate WaSH facilities and food insecurity. In 2016, diarrhoea resulted in 74.4 million disability-adjusted life-years (DALYs) (Troeger et al., 2018). Diarrhoea has been associated with high annual costs, ranging from United States Dollar (USD) $1.3–$1.7 million in Rwanda (Ngabo et al., 2016) to USD $926.4 million in China (Jin et al., 2011).

Malnutrition affects about one out of three people globally (World Health Organization [WHO], 2017a). In 2017, stunting affected 22.2% (150.8 million) of all children < 5. In 2017, while 5.6% (38.3 million) of children were overweight, 7.5% (50.5 million) were wasted or thin (Development Initiatives, 2018). Undernutrition, especially in low- and middle-income countries (LMICs), caused 45% of deaths in children < 5 (Black et al., 2013). Overweight and obesity caused ~7% of deaths (4 million) and 120 million DALYs (Naghavi & et al., 2017). Malnutrition, in all its forms, costs society ~USD $3.5 trillion, or 5% of the global gross domestic product, annually (Food and Agriculture Organization of the United Nations, 2013). Preventing children's malnutrition involves preventing infectious diseases that precipitate imbalanced protein and/or energy intake. Risk of infectious diseases, in turn, can be decreased by improving WaSH (Ashraf et al., 2020; Trinies et al., 2016). Examples of WaSH improvements include interrupting routes of faecal-oral disease transmission through proper handwashing, safe handling of food and disposal of faeces, and providing access to clean water. In 2016, 6,000 deaths due to malnutrition could have been prevented by improving WaSH (Prüss-Ustün et al., 2019).

The purpose of this study was to assess risk factors of diarrhoea, malnutrition, and dehydration in Metro Manila, Philippines. We collected data on students' health history, hydration, nutrition, hygiene practices, and WaSH-related perceptions, as well as schools' WaSH facilities and policies, in order to find out if certain child- or school-level factors increased children's risks for diseases. We collected data from a subsample of children's households, assessing demographic information, families' handwashing practice, food security, and home WaSH facilities.

2.2 Materials and methods

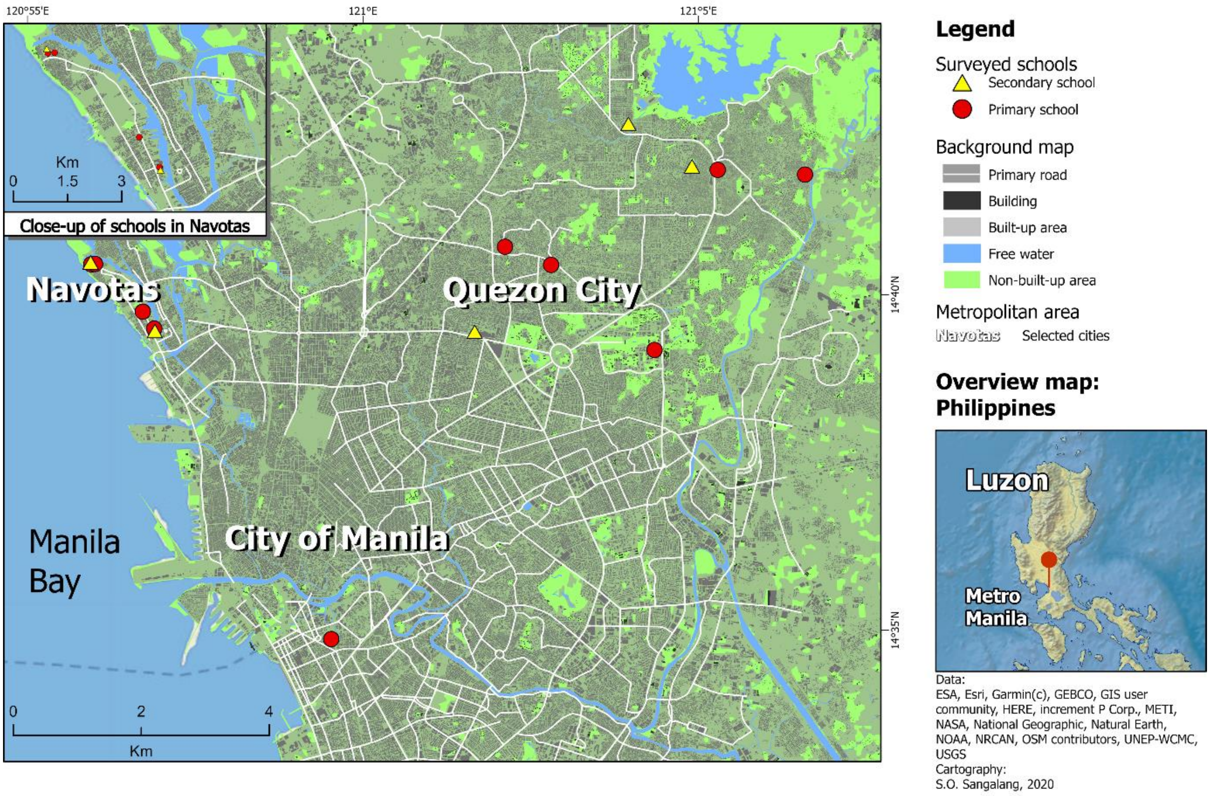
2.2.1 Study area

The Philippines has a tropical monsoon climate, with dry (December–May) and wet (June–November) seasons. The National Capital Region, known as Metro Manila, is a megacity that had ~13.5 million inhabitants in 2020 (Philippine Statistics Authority, 2021), comprising 12.4% of the country's population. In 2016, 14,800 deaths, including ~4,113 from diarrhoea, were attributed to inadequate WaSH in the Philippines (Prüss-Ustün et al., 2019). Diarrhoea is the sixth leading cause of disease in Metro Manila and among the top 10 causes of disease nationally (Philippines Department of Health, 2018). In 2018, the prevalence rates of school-age (6–10 years old) children's stunting, underweight, wasting/thinness (low weight-for-height), and overweight-for-height were: 24.5%, 25%, 7.6%, and 11.7%, respectively (Vargas, 2019). Over 29,000 annual deaths of children < 5 in the Philippines were attributed to undernutrition (United Nations International Children's Emergency Fund [UNICEF], 2018). While undernutrition alone costs the Philippines USD $4.4 million annually (UNICEF, 2018), the overall cost of hunger was USD $6.5 billion in 2013 (Save the Children Philippines, 2016).

The Philippines Department of Education operates 54,602 public schools nationally and hosted > 22.6 million children during school year 2018–2019 (Philippines Department of Education, 2019a). While public schools receive government funding, they are often severely under-staffed, have a shortage of classrooms, and are frequently overcrowded. The country's poorest children attend public schools.

2.2.2 Study design, sampling, and sample estimation

We conducted a school-based survey on a multistage cluster sample of primary and secondary school students from 15 public schools in Metro Manila, where prevalence rates of diarrhoea and malnutrition are high but access to environmental health and hygiene education is low. This paper describes a cross-sectional study that took place during the dry season and the beginning of the wet season (February–June 2017), was observational, and part of a larger research project, “WaSH in Metro Manila Schools”, which involved developing and evaluating a comprehensive, school-based WaSH intervention package. We focused on two cities in Metro Manila, Navotas and Quezon City (Figure 2.1), because they are considered geographically and socio-demographically representative of the 14 other cities that constitute Metro Manila. Our sampling frame (Figure 2.2) was the total number of public schools in Navotas and Quezon City, which consisted of 164 schools in 160



“barangays” (the smallest government units in the Philippines) in eight legislative districts.

Figure 2.1 Map of study area. The map shows the study area in the Philippines’ National Capital Region, known as Metro Manila. Points mark the location of study schools. In the lower left inset map, the red pushpin marker indicates where the location of the study area is within the Philippines, specifically in the northern most island group of Luzon.

During the first stage of sampling, we obtained annual school enrolment data for school year 2015–2016 from the Philippines Department of Education (2019a), identified all public primary schools in Navotas and Quezon City, and sorted them by enrolment size, from largest to smallest. We selected 25 schools from the top of the sorted list to invite to participate in our study. After applying our inclusion criteria (i.e., accessibility of classrooms during school-day hours and availability of WaSH facilities), we identified 15 schools to visit and ask permission from school principals to conduct our survey. One of the 15 schools had served as the location of our previous pilot study wherein we tested our survey instruments. A 16th school, located in the city of Manila, asked us directly to participate in the study. Before we finished our recruitment of study participants, one of the schools we invited to join refused to participate in the study. Thus, our final study sample came from 15 out of 16 originally contacted schools in three cities (participation rate: 93.8%). During the second stage of sampling we asked school principals, or representatives who were familiar with students' schedules, to select the class section(s) that we would survey based on scheduling availability to help us comply with the Philippines Department of Education's "no disruption of class" policy. Applying our inclusion criteria, of recruiting students in grade five or six (ages ~10-11 years old) from primary schools and students in grade seven, nine, or 10 (ages ~12-15 years old) from secondary schools, school principals/representatives selected the class section(s). Based on the school's enrolment size, one to three class sections per school were selected in order to obtain a target sample of ~100 students per school. All students belonging to the selected class section(s) were invited to participate in our study if they met our inclusion criteria: able to 1) read, comprehend, and answer our questionnaire; 2) operate an electronic tablet independently or with minimal assistance; 3) provide a urine specimen; and 4) be measured for height and weight.

Prior to starting field research, we estimated the sample size. Our target population was all the public school children in Metro Manila. There was a total of 2,059,447 public school children (1,373,852 elementary and 685,595 secondary school children) in Metro Manila in school year 2014–2015 (Philippines Department of Education, 2019a). For this baseline survey, in order to estimate proportion parameters in schoolchildren, the precision of a 95% CI should be five percentage points. As the prevalence is not known (assumed to be 50%), the sample size was estimated as N=399 under a finite population size of ~2.1 million (based on the Philippines Department of Education data for school year 2014-2015). The sample size was calculated via PASS (NCSS) software (2006 version). We inflated the sample by 30% to account for nonresponse and 45% for refusal. To account for differences in schools' enrolment sizes and the possible effects of the study design, we inflated the sample by another 45% and 20%, respectively. Our target sample size was N = 1,309, and 1,558 students enrolled in the study. We received complete responses to questions about outcomes and exposures of interest from 1,296 students (response rate: 83.2%).” We conducted household surveys on a subsample of students and their parents/guardians as described below.

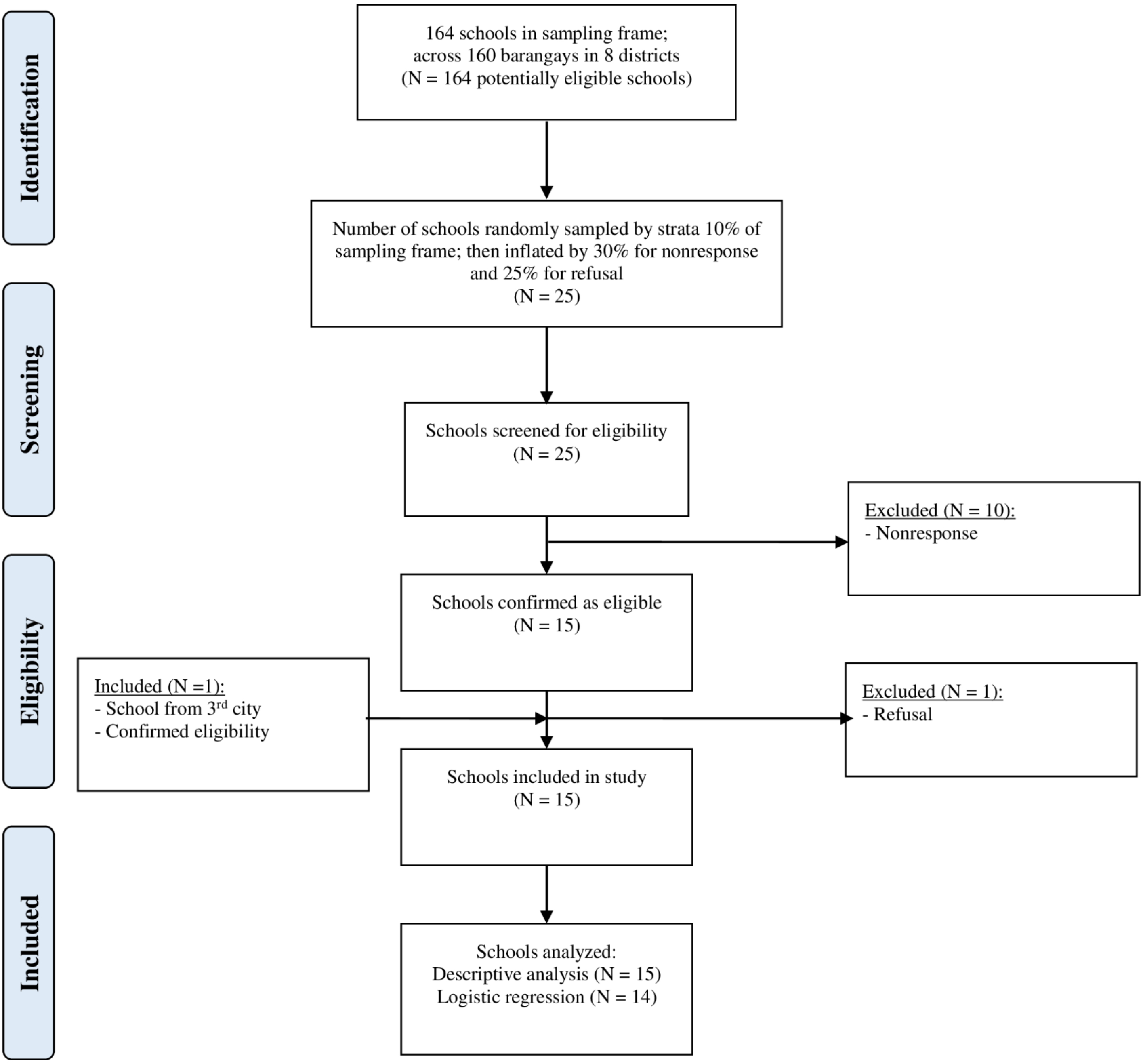


Figure 2.2 Flow diagram of recruitment of public schools showing school selection, inclusion, and analysis.

2.2.3 Data collection

We developed a self-administered questionnaire (Supplementary materials, Table S2.1) in English for students and then translated it into Tagalog (Filipino language). We developed structured interview scripts for school principals and parents, school and home restroom inspection checklists, and student health examination data entry forms. We pilot tested these electronic survey instruments at one school, and then refined them to improve understandability. Except for the students' health examination data entry forms, which we preserved as Microsoft Excel© files, the final versions of all survey instruments were administered using the QuickTapSurvey© app installed on password-protected electronic tablets.

Research assistants received hands-on training from the research supervisor during a one-day workshop prior to conducting field research. To begin the school survey, we went to schools, and research assistants gave a simple explanation in Tagalog about the study to the students, who were assigned a study identification number, which students were instructed to input into questionnaires instead of their names to ensure anonymity and confidentiality. Research assistants measured students' height (without shoes), using a standard tape measure attached to the classroom or hallway wall, and weight (without shoes or items inside their pockets), using a standard digital weighing scale [EKS Asia Ltd., Hong Kong, People's Republic of China]. Research assistants performed point-of-care urine analysis on students' urine specimens, using urine test strips [Insight Urinalysis Reagent Strips, Acon Laboratories Inc., San Diego, California, U.S.A.]. Research assistants completed the school restroom inspection checklist and took digital photos of WaSH facilities (toilets, urinals, handwashing basins); they also interviewed school principals/representatives about school WaSH policies. The research supervisor verified adherence to research protocols via direct observation. We obtained other school data, e.g., annual budget for maintenance and other operating expenses, from the Philippines Department of Education (2019a; 2019b, 2019c).

2.2.4 Dependent variables

We measured diarrhoea prevalence via students' self-report assessed by a questionnaire. The rationale for using self-report were: reliability, validity, convenience, and the ability to quickly, affordably, and accurately assess prevalence in a large sample of children. In our study, diarrhoea was defined as a numeric answer greater than zero to one question in the questionnaire ("How many times have you had diarrhoea in the last month?"). We used the WHO's definition of diarrhoea, i.e., having ≥ three loose/liquid bowel movements (i.e., passing stools or faeces) in one day (WHO, 2017b).

We measured stunting, undernutrition, and over-nutrition as follows: 1) We used anthropometry to measure children's height and weight; 2) we used the WHO AnthroPlus software (WHO, Geneva, Switzerland) to calculate z-scores; 3) we used the WHO 2007 Growth Reference for children 5–19 years old (de Onis et al., 2007) and WHO's cut-off points for z-scores to classify children's nutrition status (WHO, 2007a, 2007b). "Stunting" was defined as having a height-for-age z-score (HAZ) < -2 (Supplementary materials, Table S2.2). We considered "undernourished" to be a composite variable, i.e., comprised of two variables. First, we considered "underweight" (or "thin"), which is based on body mass index (BMI)-for-age z-score (BAZ). BMI is calculated with the formula: weight (kg) / [height (m)]2. The cut-off points for z-scores for "underweight" are -3 < BAZ < -2. Second, we defined "wasted" (or "severely thin") as BAZ < -3. We considered "over-nourished" to be a composite variable, i.e., comprised of two variables. First, we defined "overweight" as 1 < BAZ < 2. Second, we defined "obese" as BAZ > 2.

Dehydration was defined as having highly concentrated urine, i.e., urine specific gravity (U_{sg}) ≥ 1.020 (Pagana et al., 2015), measured using urine test strips (Insight Urinalysis Reagent Strips, Acon Laboratories Inc., San Diego, California, U.S.A.). We used the cut-off point of U_{sg} 1.020 because it corresponds to an urine osmolality (U_{osm}), which is considered to be the gold standard of urine-based measures of dehydration (Armstrong et al., 1994), that of 800 mOsm/kg H2O. This is the cut-off point used in previous studies involving dehydrated children (Bar-David et al., 2005). We defined mild, moderate, and severe dehydration as U_{sg} of 1.020, 1.025, and 1.030, respectively.

2.2.5 Independent variables

We assessed risk factors at the individual- and school-levels. We defined children as individuals < 13 years old and teenagers as individuals ≥ 13 years old. We asked students about handwashing, use of and perceptions about school WaSH facilities, their health history and nutrition, and if hygiene lessons were taught in school. We asked school principals about WaSH-related school policies. We counted the number and assessed the quality of school WaSH facilities, noting characteristics of improved versus unimproved sanitation (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2010). We estimated student-to-toilet and student-to-handwashing basin ratios based on the Philippines Department of Health guidelines (1998), which do not include specific or fixed ratios (Supplementary materials, Table S2.2). Rather they recommend a range of numbers for WaSH facilities that are sex-specific. We decided not to base our estimations on the WHO guidelines (WHO et al., 2009) (Supplementary materials, Table S2.2) because public schools in many parts of the Philippines, similar to other LMICs, currently have limited capacity to effectively address the over-crowding of students on school campuses. We provide operational definitions in Supplementary materials, Table S2.2.

We conducted a survey with a subsample of students' households to assess risk factors, e.g., food security, access to drinking water, at the home level. If a student provided a functioning telephone number during the questionnaire portion of the school survey, then his/her parent/guardian was contacted by a research assistant to be recruited for the household survey. Our main interest was to estimate the children's parameters with certain precision (±5%) but not the parameters of their background (e.g. family, household environment), as this was beyond the scope of our study. Therefore, this limitation to 20% of the background information was determined by the feasibility of the overall study only. We aimed to sample ~10-12 parents/guardians per school and to inflate the sample by 10% to account for nonresponse or refusal. The target sample was N=225 parents/guardians. We collected samples for tests of water quality, specifically faecal contamination, from study schools and a separate sample of households (located in the school neighbourhood) in April 2018. We report our water quality indicators in Supplementary materials, Table S2.3. We assessed water samples according to the 2017 Philippine National Standards for Drinking Water (Philippines Department of Health, 2017).

2.2.6 Statistical analysis

We downloaded data from the QuickTapSurvey© app as Microsoft Excel© files. We used key matching data (students' self-reported date of birth and telephone number) to link data from students' questionnaires and health examinations to home restroom inspections and parents'/guardians' interviews. We used Stata, version 15 (StataCorp, College Station, Texas, U.S.A.), to prepare data for analysis.

To describe exposure to inadequate WaSH, we measured frequencies and interquartile ranges (IQRs) relevant to schools' and homes' WaSH facilities. Data from school inspections were summarized at the school-level by measuring the mean scores of individual facility inspections. To describe outcomes of diarrhoea and malnutrition, we measured prevalence rates of diseases using contingency tables with estimates of standard error (SE) and 95% confidence intervals (CI).

To identify statistically significant factors associated with diarrhoea, malnutrition, and dehydration, we used multiple logistic regression (Supplementary materials, Table S2.4), which produces adjusted odds ratios (aORs). In contrast to unadjusted ORs, aORs allowed us to control for confounding. We considered the following potential confounders: children's sex, age group, self-reported food intake and health status, hygiene behaviours, and WaSH-related perceptions, and schools' WaSH facilities (quantity, quality) and related policies and budget. We considered p-values < 0.05 to be statistically significant.

For all multiple logistic regression models, clustering was controlled for by using the "cluster" option in Stata. It is important to account for clustering because of the potential for within-group ("intragroup") correlation among children from the same school and to adjust the SE of estimates. The "cluster" option in Stata enabled us to indicate that the observations were clustered into schools (based on school identification number) and that the observations may be correlated within schools, but would be independent between schools.

We analysed the main study sample with multiple logistic regression models, including variables such as: student does not wash hands in school, school restroom lacks water, and school lacks policy for cleaning restrooms daily. We analysed the subsample with multiple logistic regression models, including variables such as: the home restroom is not clean, it has signs of mould, and the number of adults in the home.

2.2.7 Ethics

Ethical approval for this study was granted by the Ethics Committees of the University of Bonn, Germany (approval date: 28 September 2016; reference number: 216/16), and the

University of the Philippines Manila (approval date: 23 February 2017; reference number: 2017-0113). We obtained written approval from the Philippines Department of Education through division superintendents. As per local procedure, we obtained written informed consent from school principals "in loco parentis", i.e., in the place of a parent. In Tagalog, we described to the children the study procedures and stated that participation in our study was voluntary and that anyone could decide to stop participating in the study anytime.

2.3 RESULTS

2.3.1 Description of study population and WaSH characteristics

We measured diarrhoea, malnutrition, and dehydration prevalence in 1,558 students from 15 schools in three cities (Supplementary materials, Table S2.5). Students were 9–19 years old; 66.7% (1,039) were < 13 years old and 73.1% (1,085) considered themselves to be "healthy" (Table 2.1). Over 16% (239) of students said they avoided the school restroom and, while > 91% of students (1,359) said they washed their hands at school, only 53% (554) said they washed their hands with soap and water at school.

Table 2.1 Characteristics of main sample of students (N = 1,558) and schools (N = 15).

	n	% (95% CI)
Student factors (N = 1,588)		
Sex (self-reported)		
Female (self-reported)	861	55.3 (52.8, 57.7)
School attendance (self-reported)		
Attended school in the last 6 months	1,391	93.5 (92.2, 94.7)
Missed class last year due to health problem or illness	610	41(38.5, 43.5)
Grade group (observed)		
Primary (grades 5–6; ~ages 10-11 years old)	1,012	65 (62.6, 67.3)
Age (self-reported)		
Median (IQR)		12 (11, 13)
Age group (self-reported)		
Child (age < 13 years)	1,039	66.7 (64.3, 69.0)
Adolescent (age ≥ 13 years)	518	33.2 (30.9, 35.6)
Health-related knowledge, perceptions, and hygiene practices (self-reported)		
Does not wash hands at school	129	8.67 (7.2, 10.1)

Does not use soap when washing hands at school	491	47 (44.0, 50.0)
Does not use school restroom	107	7.19 (5.9, 8.5)
Avoids school restroom	239	16.1 (14.2, 18)
Does not know if he/she had helminth infection	318	21.4 (19.4, 23.5)
Considers oneself to be "not healthy"	399	26.9 (24.6, 29.1)
No provision of hygiene lessons at school	135	9.1 (7.6, 10.6)
Infectious disease (self-reported)		
Had diarrhoea (in the last month)	421	28.5 (26.2, 30.9)
Had helminth infection (ever)	647	43.6 (41.1, 46.2)
Malnutrition[a] (observed)		
Stunted	227	15.2 (13.4, 17.1)
Undernutrition	127	8.6 (7.2, 10.1)
Wasted (“severely thin”)	28	1.9 (1.3, 2.7)
Underweight (“thin”)	99	6.7 (5.5, 8.1)
Overnutrition	321	21.7 (19.6, 23.9)
Overweight	226	15.3 (13.5, 17.2)
Obese	95	6.4 (5.2, 7.8)
Sign of acute dehydration (observed)		
Highly concentrated urine, $U_{sg} \geq 1.020$	956	68.0 (65.5, 70.5)
School factors		
Number of schools with unimproved[b] sanitation present	1	7.1 (0.2-33.9)
Number of schools without handwashing basin	1	14.3 (1.8, 42.8)
Type of toilet, latrine (e.g. dry, non-flush)	1	1.3 (0.03, 6.9)
Type of toilet, pour-flush	56	74.7 (59.6, 80.6)
Type of toilet, flush	16	24.1 (12.0, 30.8)
Number of toilet bowls, median (IQR)		17 (5.9, 26.5)
Number of handwashing basins, median (IQR)		5 (4, 12.5)
Number of schools that exceeded guidelines for student-to-toilet ratio[c]	13	92.9 (66.2, 99.8)
Number of schools that exceeded guidelines for student-to- handwashing unit ratio[c,d]	13	92.9 (66.2, 99.9)
Student-to-toilet ratio, median (IQR)		302.3 (219, 418)
Student-to- handwashing basin ratio, median (IQR)		562 (380.3, 935.1)
Number of toilets that had no nearby handwashing basin	24	30.4 (20.5, 41.8)
Number of handwashing basins not near toilet	61	49.2 (40.1, 58.3)
Provision of no separate toilet for females	8	3.6 (1.5, 6.8)
No water available	26	32.9 (22.7, 44.4)
No soap available	65	82.3 (72.1, 90.0)

Note CI, confidence interval; IQR, interquartile range;; U_{sg}, urine specific gravity; WaSH, water, sanitation, and hygiene.; WHO, World Health Organization. When estimating some proportions the denominator was not always N = 1,558 due to missing data.

[a]Malnutrition indices are defined in Appendix 2 and were estimated using WHO AnthroPlus software. We classified malnutrition status according to WHO guidelines (de Onis et al., 2007; WHO, 2007a, 2007b).
[c]We referred to the national guidelines (Philippines Department of Health, 1998). We estimated student-to-toilet and student-to-handwashing unit ratios by using school enrolment data from school year 2016–2017 (Philippines Department of Education, 2019a). Then we divided the number of students by two to take into account schools' use of a "double shift". We divided the number of students by the total number of toilets, taking into account that some toilets were coed toilets (i.e. used by both males and females). We report sex-specific ratios in the Supporting Information.
[d]We included in the analysis one school which had no functioning handwashing stations or basins (i.e. sinks); rather, a hose connected to water was provided for children to wash their hands.

During our assessment of associated risk factors of diseases, we excluded 266 students (17.1%): 167 because of nonresponse on outcomes or logistic regression model covariates and 99 (6.4%) because they attended a school where the school principal declined our request to inspect the school restrooms during the baseline study.

We found handwashing basins in ~86% of schools (12); ~33% (26) of handwashing basins lacked water and > 82% (65) lacked soap (Table. 2.2). Over 33% (4) of schools had water that was contaminated by coliform bacteria, while 24% (3) had water that was contaminated by *Escherichia coli* (*E. coli*) (Supplementary materials, Table S2.3).

Table 2.2 Characteristics of subsample of students, households, and homes (N = 211).

Factors	n	% (95% CI)
Student level		
Female	134	63.5 (56.6, 70.0)
Age < 13 years old	153	72.5 (66.0, 78.4)
Home level		
Household demographics		
Number of people in home, median (IQR)		6 (4, 8)
Number of adults in home, median (IQR)		3 (2, 5)
Number of kids in home, median (IQR)		3 (2, 4)
Duration (years) of residence in home, median (IQR)		13 (5, 25)
Household WaSH		
Has no restroom inside home	20	10.4 (5.9, 14.3)
Has no toilet	3	1.4 (0.3, 4.5)
Has no handwashing basin	66	34.4 (27.7, 41.6)

Home restroom has no water available	8	4.2 (1.8, 8.0)
Home restroom has no soap available	25	13.0 (8.6, 18.6)
Home restroom has no hand towels	129	67.2 (60.1, 73.8)
Home restroom has no toilet paper	187	97.4 (94.0, 99.1)
Home restroom not clean	76	39.6 (32.6, 46.9)
Home restroom has signs of mould	98	51.0 (43.7, 58.3)
Home restroom has signs of damage	139	72.4 (65.5, 78.6)
Home restroom is not well-lit	83	43.2 (36.1, 50.6)
Home restroom has wet floor	145	75.5 (68.8, 81.4)
Home restroom door has no lock	85	44.3 (37.1, 51.6)
Home restroom has unimproved[a] sanitation	39	20.3 (14.9, 26.7)
Home restroom toilet cannot be flushed	140	72.9 (66.0, 79.1)
Home restroom has septic tank	57	29.7 (23.3, 36.7)
Household food insecurity		
Insufficient amount of food at home	14	6.6 (3.7, 10.9)
No place nearby to buy food	6	2.8 (1.1, 6.1)
Food prices are not affordable	16	7.6 (4.34, 12.0)
Not able to buy food	113	53.6 (46.6, 60.4)
Has experienced asking/begging someone for food	165	78.2 (72.0, 83.6)
Does not eat a variety[b] of food	13	6.2 (3.3, 10.3)
Cooks food less often than buys prepared food	20	9.5 (5.9, 14.3)
No access to drinking water	4	1.9 (0.5, 4.8)

Note CI, confidence interval; IQR, interquartile range; WaSH, water, sanitation, and hygiene. When estimating some proportions the denominator was not always N = 211 due to missing data.

[a]Unimproved sanitation does not hygienically separate human excreta from human contact (Supplementary materials, Table S2.2).

[b]Variety of food refers to e.g. fruits, vegetables, meat, and fish.

2.3.1.1 Subsample

From our main study sample, we found N = 211 students whose parent/guardian was willing to participate in our household survey. The subsample of students was 66% (134) female and ~73% of students were < 13 years old (Table 2.2). Households had a median of six people (interquartile range [IQR] 4, 8) and the median duration of residence in the home was 13 years (IQR 5, 25). We report results of water quality testing in homes in Supplementary materials, Table S2.3.

2.3.2 Measurement of health outcomes

Over 28% (421) of students reported having diarrhoea in the last month. Over 15% (227) of students were stunted, ~9% (127) were undernourished, and > 21% (321) were over-nourished. Sixty-eight percent (68%) of students (956) had highly concentrated urine ($U_{sg} \geq 1.020$), indicative of dehydration. A greater proportion of males (68.7%, 432) compared to females (67.5%, 524), and a greater proportion of teenagers (72.1%, 354) compared to children (65.9%, 602), were dehydrated (Supplementary materials, Table S2.6).

2.3.3 Associations between diarrhoea, dehydration, and school WaSH

Students' not washing their hands in school was significantly associated with increased odds of diarrhoea (aOR 1.77, 95% CI = 1.18 to 2.65) (Table 2.3). Diarrhoea risk decreased as the number of school restrooms increased (Table 2.3) and when schools had the maximum maintenance and other operating expenses budget (aOR 0.42, 95% CI = 0.31 to 0.57). The lack of water in school restrooms was associated with mild (aOR 1.84, 95% CI = 1.63 to 2.08) and moderate dehydration (aOR 2.21, 95% CI = 1.71 to 2.87). Risk of mild dehydration decreased as the number of school handwashing basins increased, while the risk of moderate dehydration decreased as the number of school toilets increased (Table 2.3).

2.3.4 Associations between malnutrition and school WaSH

Decreased risk of stunting and undernutrition was associated with schools > 50 years old and a maximum maintenance and other operating expenses budget (Table 2.4). Risk factors of stunting were not using the school restroom (aOR 2.26, 95% CI = 1.22 to 4.20), lack of water in school restrooms (aOR 1.52, 95% CI = 1.21 to 1.90), and lack of hygiene lessons (aOR 1.91, 95% CI = 1.12 to 3.26) (Table 2.4). Risk of stunting decreased as the number of school restrooms increased (Table 2.4).

Flies in school restrooms were associated with under- and over-nutrition (Table 2.4). The maximum numbers of school toilets and handwashing basins were associated with decreased risks for under- and over-nutrition (Table 2.4). Undernutrition was associated with school restrooms that lacked water (aOR 2.18, 95% CI = 1.54 to 3.09), while overnutrition was associated with school restrooms that were not accessible for person(s) with disabilities (PWDs) (aOR 1.43, 95% CI = 1.06 to 1.93).

2.3.5 Impacts of home-level factors on diarrhoea and malnutrition.

Diarrhoea was associated with not eating three times per day (aOR 5, 95% CI = 1.05 to 24.00), while mild dehydration was associated with having no handwashing basin at home (aOR 2.45, 95% CI = 1.08 to 5.56) and moderate dehydration was associated with five or more adults living at home (aOR 5.42, 95% CI = 1.59 to 18.40) (Table 2.5).

Home restrooms' having signs of mould (aOR 9.12, 95% CI = 1.89 to 44.00) and having no handwashing basin (aOR 14.00, 95% CI = 4.30 to 46.20) were associated with increased odds of stunting only (Table 2.6), as was the presence of five or more children at home (aOR 15.70, 95% CI = 1.79 to 138). A lack of food variety was associated with decreased risk of stunting (aOR 0.10, 95% CI = 0.01 to 0.90) and increased risk of undernutrition (aOR 5.56, 95% CI = 1.45 to 21.35).

2.4 DISCUSSION

2.4.1 Key findings and interpretation

The overall school WaSH situation in our study schools was characterized by deficiencies in supply, access, and functionality. Such deficiencies in school WaSH were consistent with findings from previous studies conducted in the Philippines (Ellis et al., 2016; Katsuno et al., 2019). Our findings suggest that inadequate school WaSH increases the risk of children self-reporting diarrhoea and increases risks of observed dehydration and malnutrition. We highlight four deficiencies that had negative effects on children's health and hygiene behaviour. First was the lack of water in school restrooms, which increased children's risks for dehydration and stunting. This may be explained by the fact that children, without having water to wash their hands or flush the toilet, may have been more exposed to faeces. Consequences of faecal exposure include diarrhoea, which can cause dehydration, and helminth infection, which can stunt growth if experienced repeatedly. Tap water in the Philippines is not safe for drinking. A lack of drinking water dispensers in many of our study schools likely explained the high prevalence of dehydration. Another possible reason is voluntary dehydration wherein children, in order to avoid using school toilets which they perceived to be unclean, purposefully did not drink water. When no water was available to flush faeces down the toilet, children could have found the situation disgusting or scary. Thus, they would do whatever possible (including not drinking water) in order to avoid using the toilet. A similar thing happens when adults knowingly avoid drinking fluids during long

Table 2.3 Adjusted logistic regression models of self-reported diarrhoea and observed mild and moderate dehydration among students and risk factors at public schools in Metro Manila, Philippines (N = 1,478).

Factor	**Diarrhoea (*N* = 421)**			**Mild dehydration (*N* = 214)**			**Moderate dehydration (*N* = 457)**		
	n (%)	**aOR (95% CI)**	**p-value**	**n (%)**	**aOR (95% CI)**	**p-value**	**n (%)**	**aOR (95% CI)**	**p-value**
Student level									
Demographics (self-reported)									
Sex									
Male	201 (30.6)	Ref.		103 (16.4)	Ref.		193 (30.7)	Ref.	
Female	220 (26.8)	0.94 (0.71, 1.26)	0.69	111 (14.3)	0.80 (0.54, 1.19)	0.28	264 (34)	1.18 (0.89, 1.56)	0.25
Age group: early teenager (13–14 years old)									
Yes	90 (27.7)	1.30 (0.94, 1.79)	0.11	48 (14.7)	0.75 (0.49, 1.13)	0.16	87 (26.6)	0.95 (0.63, 1.44)	0.83
No	331 (28.7)	Ref.		166 (15.4)	Ref.		370 (34.3)	Ref.	
Health & nutrition (self-reported)									
Does not eat three times per day									
Yes	36 (41.4)	1.49 (0.96, 2.32)	0.08	6 (7.8)	0.53 (0.24, 1.15)	0.11	30 (39)	1.58 (0.80, 3.13)	0.19
No	385 (27.8)	Ref.		196 (15.6)	Ref.		400 (31.9)	Ref.	
Is not “healthy”									
Yes	139 (35)	1.43 (1.03, 2)	0.03	53 (14.6)	0.93 (0.71, 1.22)	0.60	107 (29.4)	0.82 (0.65, 1.03)	0.08
No	282 (26.2)	Ref.		150 (15.5)	Ref.		325 (33.5)	Ref.	
Had helminth infection									
Yes	207 (32.1)	1.20 (0.98, 1.48)	0.08	86 (15.1)	1.05 (0.91, 1.21)	0.50	186 (32.8)	1.03 (0.81, 1.32)	0.81
No	212 (25.6)	Ref.		116 (15.2)	Ref.		244 (32)	Ref.	

Hygiene-related perception and practices (self-reported)									
Student does not wash hands at school									
Yes	45 (34.9)	1.77 (1.18, 2.65)	0.01	11 (8.9)	0.49 (0.21, 1.16)	0.11	46 (37.1)	1.05 (0.61, 1.80)	0.86
No	376 (27.9)	Ref.		192 (15.8)	Ref.		386 (31.9)	Ref.	
Student is not satisfied with school restroom									
Yes	213 (27.8)	0.89 (0.64, 1.22)	0.46	103 (14.7)	1.05 (0.81, 1.37)	0.71	238 (34)	1.13 (0.82, 1.56)	0.46
No	208 (29.3)	Ref.		100 (15.8)	Ref.		194 (30.6)	Ref.	
Student avoids using school restroom									
Yes	80 (33.9)	1.44 (0.97, 2.14)	0.07	22 (12.1)	0.87 (0.52, 1.43)	0.58	65 (35.7)	1.11 (0.70, 1.77)	0.65
No	341 (27.5)	Ref.		181 (15.7)	Ref.		366 (31.8)	Ref.	
Student does not use school restroom									
Yes	24 (23.1)	0.64 (0.38, 1.09)	0.10	4 (6.2)	0.50 (0.24, 1.05)	0.07	20 (30.8)	0.88 (0.47, 1.63)	0.68
No	397 (28.9)	Ref.		199 (15.7)	Ref.		412 (32.4)	Ref.	
Facilities (observed)									
Number of restrooms									
1–3	190 (32.8)	Ref.		71 (11.6)	Ref.		182 (29.6)	Ref.	
4–8	124 (25.1)	0.38 (0.25, 0.56)	$p < 0.01$	74 (17.1)	1.21 (1.01, 1.45)	0.03	149 (34.3)	4.98 (3.63, 6.84)	$p < 0.01$
9–15	76 (24.8)	0.34 (0.17, 0.65)	$p < 0.01$	60 (19.8)	5.61 (3.44, 9.15)	$p < 0.01$	108 (35.6)	49.7 (29.9, 82.5)	$p < 0.01$
Number of toilet bowls									
3–5	134 (33.8)	Ref.		52 (12.1)	Ref.		154 (35.9)	Ref.	
6–18	141 (29.1)	1.63 (1.19, 2.23)	$p < 0.01$	83 (16.5)	4.48 (3.51, 5.71)	$p < 0.01$	126 (25.1)	0.11 (0.08, 0.16)	$p < 0.01$
19–30	115 (23)	2 (1.15, 3.48)	0.01	70 (16.7)	2.20 (1.68, 2.90)	$p < 0.01$	159 (38)	0.02 (0.01, 0.03)	$p < 0.01$
Number of handwashing basins									

0–7	230 (29)	Ref.		107 (12.6)	Ref.		270 (31.8)	Ref.	
8–15	80 (27.1)	1.85 (1.33, 2.58)	p < 0.01	53 (17.7)	0.42 (0.33, 0.54)	p < 0.01	97 (32.3)	0.22 (0.17, 0.30)	p < 0.01
16–28	80 (27.2)	1.78 (1.20, 2.63)	p < 0.01	45 (22.2)	0.38 (0.24, 0.60)	p < 0.01	72 (35.5)	0.55 (0.33, 0.93)	0.03
Restroom lacks water									
Yes	278 (27.6)	1.18 (0.90, 1.54)	0.24	174 (16.5)	1.84 (1.63, 2.08)	p < 0.01	388 (36.7)	2.21 (1.71, 2.87)	p < 0.01
No	112 (30)	Ref.		31 (10.6)	Ref.		51 (17.4)	Ref.	
Restroom lacks cleanliness[a]									
Yes	279 (30.4)	1.24 (0.95, 1.63)	0.11	125 (14.9)	0.91 (0.66, 1.27)	0.59	290 (34.4)	1.25 (0.96, 1.63)	0.11
No	142 (25.4)	Ref.		78 (15.8)	Ref.		142 (28.7)	Ref.	
Restroom has flies									
Yes	78 (26)	0.81 (0.63, 1.04)	0.10	36 (11.7)	0.45 (0.38, 0.54)	p < 0.01	120 (38.3)	9.17 (7.19, 11.7)	p < 0.01
No	312 (28.9)	Ref.		169 (16.2)	Ref.		319 (30.6)	Ref.	
Restroom not accessible for person(s) with disability [a]									
Yes	225 (29)	1.05 (0.72, 1.52)	0.80	114 (15.5)	1.16 (0.88, 1.54)	0.30	238 (32.4)	0.87 (0.62, 1.22)	0.41
No	196 (27.9)	Ref.		89 (14.8)	Ref.		194 (32.3)	Ref.	
Long line to use restroom[a]									
Yes	116 (33.2)	1.22 (0.93, 1.61)	0.15	44 (14)	0.88 (0.62, 1.24)	0.47	114 (36.2)	1.30 (0.91, 1.86)	0.15
No	304 (27)	Ref.		159 (15.6)	Ref.		318 (31.2)	Ref.	
Administration (self-reported)									
Lack of policy for cleaning restroom daily									
Yes	29 (27.4)	0.57 (0.41, 0.78)	p < 0.01	19 (19)	0.24 (0.18, 0.30)	p < 0.01	39 (39)	2.03 (1.61, 2.56)	p < 0.01
No	392 (28.6)	Ref.		195 (14.9)	Ref.		418 (32)	Ref.	

Hygiene lessons are not taught in school									
Yes	37 (27.8)	0.84 (0.60, 1.17)	0.31	14 (12.4)	1.12 (0.57, 2.20)	0.74	37 (32.7)	0.74 (0.48, 1.13)	0.16
No	384 (28.7)	Ref.		189 (15.5)	Ref.		392 (32.2)	Ref.	
Age of school > 50 years									
Yes	193 (33.3)	1.78 (1.37, 2.30)	p < 0.01	100 (16.7)	2.99 (2.39, 3.74)	p < 0.01	194 (32.4)	0.70 (0.55, 0.89)	p < 0.01
No	228 (25.4)	Ref.		114 (14.1)	Ref.		263 (32.6)	Ref.	
Maximum maintenance and other operating expenses budget ≥ $350,000 USD[b]									
Yes	40 (21.7)	0.42 (0.31, 0.57)	p < 0.01	33 (17.5)	0.62 (0.48, 0.81)	p < 0.01	52 (27.5)	3.07 (2.28, 4.13)	p < 0.01
No	381 (29.4)	Ref.		181 (14.9)	Ref.		405 (33.3)	Ref.	

Note aOR, adjusted odds ratio; CI, confidence interval; Ref., reference group; USD, United States Dollar.
[a]Self-reported by students.
[b]Data source: (Philippines Department of Education, 2019c)
aORs were estimated by multiple logistic regression models. Variables of exposure included in models were: female, early-teenager (age 13–14 years old), does not eat three times per day, does not consider self to be “healthy”, had helminth infection, does not wash hands in school, is not satisfied with school restroom, avoids school restroom, does not use school restroom, number of school restrooms, number of school toilets, number of school handwashing basins, school restroom lacks water, school restroom is not clean, school restroom has flies, school restroom is not accessible for persons with disability, long lines to use school restroom, lack of policy to clean school restroom daily, hygiene lessons are not taught in school, age of school > 50 years, and maximum maintenance and other operating expenses budget.

Table 2.4 Adjusted logistic regression models of observed malnutrition among students and risk factors at public schools in Metro Manila, Philippines (N = 1,478).

Factor	Stunted only (*N*= 186)			Undernutrition only (*N* = 87)			Overnutrition only (*N* = 306)		
	n (%)	aOR (95% CI)	p-value	n (%)	aOR (95% CI)	p-value	n (%)	aOR (95% CI)	p-value
Student level (self-reported)									
Student characteristics									
Sex									
Male	80 (12.1)	Ref.		51 (7.7)	Ref.		154 (23.4)	Ref.	
Female	106 (12.9)	1.18 (0.77, 1.81)	0.46	36 (4.4)	0.65 (0.36, 1.17)	0.15	152 (18.6)	0.67 (0.44, 1.01)	0.06
Age group: early teenager (13–14 years old)									
Yes	37 (11)	1.42 (0.76, 2.64)	0.27	17 (5.1)	0.65 (0.38, 1.11)	0.11	53 (15.8)	0.85 (0.53, 1.36)	0.49
No	149 (13.1)	Ref.		70 (6.1)	Ref.		253 (22.2)	Ref.	
Health & nutrition (self-reported)									
Does not eat three times per day									
Yes	14 (17.7)	1.02 (0.56, 1.88)	0.94	4 (5.1)	0.80 (0.33, 1.92)	0.62	14 (17.7)	1.24 (0.63, 2.46)	0.53
No	158 (11.9)	Ref.		77 (5.8)	Ref.		278 (21)	Ref.	
Is not "healthy"									
Yes	55 (14.2)	1.28 (0.73, 2.24)	0.38	33 (8.5)	1.82 (1.24, 2.67)	p < 0.01	42 (10.9)	0.37 (0.23, 0.59)	p < 0.01
No	117 (11.5)	Ref.		49 (4.8)	Ref.		250 (24.5)	Ref.	
Had diarrhoea									
Yes	62 (15.3)	1.45 (1.10, 1.93)	0.01	23 (5.7)	1 (0.64, 1.56)	1	86 (21.2)	1.14 (0.90, 1.45)	0.26
No	110 (11)	Ref.		57 (5.7)	Ref.		207 (20.7)	Ref.	
Was dehydrated									

Yes	113 (11.8)	0.81 (0.59, 1.11)	0.20	62 (6.5)	1.75 (1.09, 2.81)	0.02	201 (21)	1.22 (0.94, 1.58)	0.13
No	62 (13.8)	Ref.		21 (4.7)	Ref.		88 (19.6)	Ref.	
Had helminth infection									
Yes	106 (17.4)	1.65 (1.13, 2.43)	0.01	45 (7.4)	1.56 (1.08, 2.24)	0.02	101 (16.6)	0.68 (0.51, 0.90)	0.01
No	66 (8.3)	Ref.		37 (4.7)	Ref.		192 (24.2)	Ref.	
Hygiene-related perception and practices (self-reported)									
Does not wash hands in school									
Yes	15 (11.8)	1.06 (0.45, 2.53)	0.89	7 (5.5)	0.77 (0.32, 1.83)	0.55	23 (18.1)	1 (0.70, 1.44)	1
No	158 (12.3)	Ref.		75 (5.9)	Ref.		270 (21.1)	Ref.	
Is not satisfied with school restroom									
Yes	73 (9.8)	0.63 (0.44, 0.90)	0.01	44 (5.9)	0.84 (0.45, 1.59)	0.59	161 (21.7)	1.06 (0.75, 1.51)	0.73
No	100 (15.1)	Ref.		38 (5.7)	Ref.		131 (19.7)	Ref.	
Avoids using school restroom									
Yes	26 (13.1)	0.71 (0.43, 1.16)	0.17	16 (8.1)	1.58 (0.55, 4.52)	0.39	40 (20.2)	0.93 (0.64, 1.34)	0.70
No	147 (12.2)	Ref.		66 (5.5)	Ref.		253 (20.9)	Ref.	
Does not use school restroom									
Yes	14 (20)	2.26 (1.22, 4.20)	0.01	5 (7.1)	0.96 (0.25, 3.66)	0.95	13 (18.6)	1.09 (0.59, 2)	0.78
No	159 (11.9)	Ref.		77 (5.8)	Ref.		280 (20.9)	Ref.	
School level Facilities (observed)									
Number of restrooms									
1–3	109 (17.6)	Ref.		38 (6.1)	Ref.		122 (19.7)	Ref.	

4–8	37 (8.2)	0.34 (0.24, 0.47)	p < 0.01	24 (5.3)	0.75 (0.45, 1.25)	0.27	103 (22.8)	3.28 (2.60, 4.13)	p < 0.01
9–15	20 (6.5)	0.08 (0.04, 0.14)	p < 0.01	21 (6.8)	5.59 (2.96, 10.6)	p < 0.01	65 (21)	15.7 (10.2, 24.3)	p < 0.01
Number of toilet bowls									
3–5	90 (20.8)	Ref.		29 (6.7)	Ref.		83 (19.2)	Ref.	
6–18	48 (9.5)	0.42 (0.27, 0.67)	p < 0.01	24 (4.7)	0.81 (0.44, 1.46)	0.48	109 (21.5)	1.12 (0.84, 1.50)	0.44
19–30	28 (6.3)	0.51 (0.27, 0.94)	0.03	30 (6.8)	0.44 (0.20, 0.94)	0.03	98 (22.2)	0.60 (0.41, 0.88)	0.01
Number of handwashing basins									
0–7	125 (14.7)	Ref.		52 (6.1)	Ref.		169 (19.8)	Ref.	
8–15	22 (7.3)	5.93 (4.49, 7.83)	p < 0.01	17 (5.7)	1.04 (0.70, 1.53)	0.85	68 (22.6)	0.26 (0.20, 0.33)	p < 0.01
16 or more	19 (8.4)	8.17 (5.61, 11.9)	p < 0.01	14 (6.2)	0.23 (0.14, 0.39)	p < 0.01	53 (23.5)	0.32 (0.21, 0.50)	p < 0.01
Restroom has no water available									
Yes	130 (12.2)	1.52 (1.21, 1.90)	p < 0.01	69 (6.5)	2.18 (1.54, 3.09)	p < 0.01	214 (20)	0.49 (0.43, 0.56)	p < 0.01
No	36 (11.5)	Ref.		14 (4.5)	Ref.		76 (24.4)	Ref.	
Restroom is not clean									
Yes	98 (11.1)	0.67 (0.48, 0.94)	0.02	49 (5.5)	0.94 (0.55, 1.60)	0.81	204 (23)	1.28 (0.92, 1.80)	0.15
No	75 (14.4)	Ref.		33 (6.3)	Ref.		89 (17.1)	Ref.	
Restroom has flies									
Yes	25 (8.1)	0.90 (0.65, 1.25)	0.53	16 (5.2)	1.61 (1.03, 2.52)	0.04	86 (27.8)	1.70 (1.27, 2.29)	p < 0.01
No	141 (13.2)	Ref.		67 (6.3)	Ref.		204 (19.1)	Ref.	
Restroom not accessible for person(s) with disability [d]									
Yes	86 (11.2)	0.85 (0.57, 1.29)	0.45	48 (6.2)	1.21 (0.72, 2.02)	0.47	176 (22.9)	1.43 (1.06, 1.93)	0.02
No	87 (13.6)	Ref.		34 (5.3)	Ref.		117 (18.3)	Ref.	

Long line to use restroom[d]									
Yes	46 (13.8)	1.12 (0.75, 1.66)	0.59	16 (4.8)	0.82 (0.48, 1.41)	0.48	52 (15.6)	0.62 (0.45, 0.86)	p < 0.01
No	127 (11.8)	Ref.		66 (6.2)	Ref.		241 (22.4)	Ref.	
Administration and policies (self-reported)									
No policy to clean school restroom daily									
Yes	7 (6.6)	0.98 (0.70, 1.38)	0.91	4 (3.8)	1.65 (0.98, 2.80)	0.06	26 (24.5)	0.46 (0.34, 0.61)	p < 0.01
No	179 (13.1)	Ref.		83 (6.1)	Ref.		280 (20.4)	Ref.	
Hygiene lessons are not taught in school									
Yes	23 (19.3)	1.91 (1.12, 3.26)	0.02	7 (5.9)	0.87 (0.15, 5.20)	0.88	19 (16)	1.05 (0.52, 2.11)	0.89
No	148 (11.5)	Ref.		74 (5.8)	Ref.		274 (21.3)	Ref.	
Age of school > 50 years									
Yes	82 (13.5)	0.64 (0.46, 0.90)	0.01	24 (4)	0.39 (0.25, 0.61)	p < 0.01	147 (24.2)	2.60 (1.99, 3.42)	p < 0.01
No	104 (11.9)	Ref.		63 (7.2)	Ref.		159 (18.3)	Ref.	
Maximum maintenance and other operating expenses; budget ≥ $350,000 USD[b]									
Yes	8 (4.2)	0.34 (0.21, 0.54)	p < 0.01	12 (6.3)	0.57 (0.34, 0.95)	0.03	35 (18.4)	1.08 (0.79, 1.47)	0.63
No	178 (13.8)	Ref.		75 (5.8)	Ref.		271 (21)	Ref.	

Note aOR, adjusted odds ratio; CI, confidence interval; Ref., reference group; USD, United States Dollar.

[a]Self-reported by students.

[b]Data source: (Philippines Department of Education, 2019c)

aORs were estimated by multiple logistic regression models. Variables of exposure included in models were: female, early-teenager (age 13–14 years old), does not eat three times per day, does not consider self to be “healthy”, had diarrhoea, is dehydrated (urine specific gravity ≥

1.020), had helminth infection, does not wash hands in school, is not satisfied with school restroom, avoids school restroom, does not use school restroom, number of school restrooms, number of school toilets, number of school handwashing basins, school restroom lacks water, school restroom is not clean, school restroom has flies, school restroom is not accessible for persons with disability, long lines to use school restroom, lack of policy to clean school restroom daily, hygiene lessons are not taught in school, age of school > 50 years, and maximum maintenance and other operating expenses budget.

Table 2.5 Adjusted logistic regression models of self-reported diarrhoea and observed dehydration among subsample of students and risk factors at public schools in Metro Manila, Philippines (N = 211).

Factor	**Diarrhoea (*N* = 56)**			**Mild dehydration (*N* = 30)**			**Moderate dehydration (*N* = 63)**		
	n (%)	**aOR (95% CI)**	**p-value**	**n (%)**	**aOR (95% CI)**	**p-value**	**n (%)**	**aOR (95% CI)**	**p-value**
Student level (self-reported)									
Student characteristics									
Sex									
Male	19 (24.7)	Ref.		11 (14.3)	Ref.		20 (26)	Ref.	
Female	37 (27.6)	1.45 (0.82, 2.56)	0.20	19 (14.3)	1.05 (0.28, 3.95)	0.95	43 (32.3)	1.35 (0.63, 2.90)	0.44
Age group: early teenager (13–14 years old)									
Yes	12 (29.3)	1.12 (0.38, 3.33)	0.83	6 (14.6)	1.25 (0.47, 3.31)	0.65	8 (19.5)	0.39 (0.18, 0.84)	0.02
No	44 (25.9)	Ref.		24 (14.2)	Ref.		55 (32.5)	Ref.	
Health & nutrition (self-reported)									
Does not eat three times per day									
Yes	5 (62.5)	5 (1.05, 24)	0.04	0	n/a		4 (50)	1.60 (0.25, 10.2)	0.62
No	51 (25.1)	Ref.		30 (14.9)			59 (29.2)	Ref.	
Is not “healthy”									
Yes	20 (37)	1.79 (0.91, 3.53)	0.09	9 (16.7)	1.55 (0.55, 4.33)	0.41	15 (27.8)	0.90 (0.33, 2.47)	0.83
No	36 (22.9)	Ref.		21 (13.5)	Ref.		48 (30.8)	Ref.	
Had helminth infection									
Yes	26 (33.8)	2.25 (0.90, 5.61)	0.08	11 (14.5)	1.61 (0.57, 4.49)	0.37	23 (30.3)	0.71 (0.32, 1.55)	0.39
No	19 (21.4)	Ref.		11 (12.4)	Ref.		28 (31.5)	Ref.	
Hygiene-related perception and practices (self-reported)									

Does not wash hands in school									
Yes	9 (40.9)	2.08 (0.96, 4.52)	0.06	3 (13.6)	0.23 (0.06, 0.93)	0.04	5 (22.7)	0.84 (0.24, 2.91)	0.78
No	47 (24.9)	Ref.		27 (14.4)	Ref.		58 (30.9)	Ref.	
Does not use school restroom									
Yes	2 (22.2)	0.13 (0.01, 1.46)	0.10	2 (22.2)	3.79 (0.20, 70.9)	0.37	2 (22.2)	0.55 (0.07, 4.53)	0.58
No	54 (26.7)	Ref.		28 (13.9)	Ref.		61 (30.4)	Ref.	
Hygiene lessons are not taught in school									
Yes	4 (21.1)	0.72 (0.14, 3.58)	0.68	1 (5.3)	0.44 (0.04, 4.77)	0.50	5 (26.3)	1 (0.21, 4.73)	1
No	52 (27.1)	Ref.		29 (15.2)	Ref.		58 (30.4)	Ref.	
Household level									
Number of adults									
1–2	26 (27.1)	Ref.		14 (14.6)	Ref.		21 (21.9)	Ref.	
3–4	14 (22.6)	1.03 (0.50, 2.11)	0.94	9 (14.5)	1.10 (0.46, 2.66)	0.83	18 (29)	1.57 (0.61, 4.04)	0.35
≥ 5	16 (30.2)	1.10 (0.45, 2.69)	0.83	7 (13.5)	0.55 (0.12, 2.61)	0.45	24 (46.2)	5.42 (1.59, 18.4)	0.01
Number of children									
1–2	20 (20.8)	Ref.		15 (15.6)	Ref.		32 (33.3)	Ref.	
3–4	31 (34.4)	2.31 (0.85, 6.31)	0.10	8 (9)	0.58 (0.21, 1.65)	0.31	21 (23.6)	0.76 (0.29, 2.02)	0.59
≥ 5	5 (20.8)	0.54 (0.10, 2.91)	0.47	6 (25)	3.72 (0.64, 21.7)	0.15	10 (41.7)	0.92 (0.29, 2.85)	0.88
Duration (years) of residence in home									
0–4	13 (28.9)	Ref.		6 (13.3)	Ref.		17 (37.8)	Ref.	
5–19	22 (25)	1.34 (0.50, 2.59)	0.76	14 (15.9)	0.97 (0.22, 4.19)	0.96	26 (29.6)	0.53 (0.20, 1.46)	0.22
≥ 20	21 (26.9)	1.05 (0.53, 2.09)	0.89	10 (13)	0.61 (0.23, 1.63)	0.33	20 (26)	0.48 (0.19, 1.25)	0.13
Does not eat a variety of food (self-reported)									
Yes	3 (23.1)	1.51 (0.49, 4.61)	0.47	3 (23.1)	1.36 (0.32, 5.72)	0.68	4 (30.8)	1.63 (0.42, 6.31)	0.48

No	53 (26.8)	Ref.		27 (13.7)	Ref.		59 (30)	Ref.	
WaSH									
No restroom inside home									
Yes	4 (20)	0.70 (0.17, 2.88)	0.62	2 (10)	0.53 (0.12, 2.26)	0.39	6 (30)	0.83 (0.18, 3.84)	0.81
No	48 (27.9)	Ref.		26 (15.2)	Ref.		47 (27.5)	Ref.	
Restroom is not clean									
Yes	23 (30.3)	1.39 (0.68, 2.85)	0.37	9 (11.8)	1.17 (0.53, 2.59)	0.71	27 (35.5)	2.03 (0.76, 5.40)	0.16
No	29 (25)	Ref.		19 (16.5)	Ref.		26 (22.6)	Ref.	
Restroom has no water									
Yes	3 (37.5)	2.24 (0.16, 32.4)	0.55	0	n/a		2 (25)	0.26 (0.02, 2.80)	0.27
No	49 (26.6)	Ref.		28 (15.3)			51 (27.9)	Ref.	
Restroom has no handwashing basin									
Yes	14 (23.3)	0.97 (0.31, 3.03)	0.96	10 (16.7)	2.45 (1.08, 5.56)	0.03	15 (25)	0.76 (0.24, 2.44)	0.64
No	38 (29)	Ref.		18 (13.9)	Ref.		37 (28.5)	Ref.	
Restroom is not well-lit									
Yes	23 (27.7)	1.03 (0.39, 2.70)	0.96	12 (14.5)	1.14 (0.50, 2.61)	0.75	24 (28.9)	0.83 (0.25, 2.74)	0.76
No	29 (27.4)	Ref.		15 (14.3)	Ref.		28 (26.7)	Ref.	
Restroom has no door lock									
Yes	22 (25.9)	0.61 (0.20, 1.85)	0.39	10 (11.8)	0.43 (0.21, 0.88)	0.02	26 (30.6)	1.69 (0.66, 4.33)	0.27
No	30 (28.3)	Ref.		18 (17.1)	Ref.		26 (24.8)	Ref.	
Restroom has signs of mould									
Yes	31 (31.6)	1.63 (0.67, 4)	0.28	14 (14.3)	0.95 (0.34, 2.63)	0.91	21 (21.4)	0.39 (0.18, 0.83)	0.02
No	21 (22.3)	Ref.		14 (15.1)	Ref.		32 (34.4)	Ref.	
No garbage bin in or near restroom									

Yes	27 (23.7)	0.82 (0.50, 2.11)	0.94	14 (12.3)	0.45 (0.21, 0.96)	0.04	33 (29)	1.44 (0.80, 2.59)	0.23
No	25 (32.1)	Ref.		14 (18.2)	Ref.		20 (26)	Ref.	

Note aOR, adjusted odds ratio; CI, confidence interval; Ref., reference group; WaSH, water, sanitation, and hygiene.
aORs were estimated by multiple logistic regression models. Variables of exposure included in models were: female, early-teenager (age 13–14 years old), does not eat three times per day, does not consider self to be "healthy", had helminth infection, does not wash hands in school, does not use school restroom, hygiene lessons are not taught in school, number of adults living in home, number of children living in home, duration (years) of residence in home, does not eat a variety of food at home, home has no indoor restroom, home restroom is not clean, home restroom has no water, home restroom has no handwashing basin, home restroom is not well-lit, home restroom has no door lock, home restroom has signs of mould, and no garbage can inside or nearby home restroom.

Table 2.6 Adjusted logistic regression models of observed malnutrition among subsample of students and risk factors at public schools in Metro Manila, Philippines (N = 211).

Factor	Stunting only (*N* = 28)			Undernutrition only (*N* = 13)			Overnutrition (*N* = 46)		
	n (%)	aOR (95% CI)	p-value	n (%)	aOR (95% CI)	p-value	n (%)	aOR (95% CI)	p-value
Student level									
Student characteristics									
Sex									
Male	7 (9.1)	Ref.		6 (7.8)	Ref.		22 (28.6)	Ref.	
Female	21 (15.7)	2.46 (0.40, 15.2)	0.33	7 (5.2)	0.55 (0.11, 2.63)	0.45	24 (17.9)	0.33 (0.18, 0.61)	p < 0.01
Age group: early teenager (13–14 years old)									
Yes	5 (12.2)	0.26 (0.04, 1.83)	0.18	1 (2.4)	0.10 (0.01, 0.72)	0.02	6 (14.6)	0.18 (0.05, 0.57)	p < 0.01
No	23 (13.5)	Ref.		12 (7.1)	Ref.		40 (23.5)	Ref.	
Health & nutrition (self-reported)									
Does not eat three times per day									
Yes	1 (12.5)	0.19 (0.03, 1.21)	0.08	0	n/a		3 (37.5)	0.58 (0.11, 3.09)	0.52
No	27 (13.3)	Ref.		13 (6.4)			43 (21.2)	Ref.	
Is not “healthy”									
Yes	12 (22.2)	2.55 (0.48, 13.6)	0.28	3 (5.6)	2.82 (0.52, 15.2)	0.23	9 (16.7)	0.42 (0.14, 1.27)	0.13
No	16 (10.2)	Ref.		10 (6.4)	Ref.		37 (23.6)	Ref.	
Diarrhoea									
Yes	8 (14.3)	2.16 (0.79, 5.94)	0.13	1 (1.8)	0.08 (0.01, 0.70)	0.02	13 (23.2)	1.58 (0.81, 3.09)	0.18
No	20 (12.9)	Ref.		12 (7.7)	Ref.		33 (21.3)	Ref.	
Dehydration									

Yes	14 (10.1)	0.49 (0.17, 1.36)	0.17	11 (7.9)	4.29 (0.53, 34.4)	0.17	32 (23)	1.50 (0.54, 4.19)	0.43
No	14 (19.7)	Ref.		2 (2.8)	Ref.		14 (19.7)	Ref.	
Had helminth infection									
Yes	17 (22.1)	2.92 (0.80, 10.7)	0.11	6 (7.8)	1.56 (0.50, 4.81)	0.44	15 (19.5)	2.38 (1, 5.70)	0.05
No	7 (7.9)	Ref.		6 (6.7)	Ref.		18 (20.2)	Ref.	
Hygiene-related perception and practices (self-reported)									
Does not wash hands in school									
Yes	5 (22.7)	2.31 (0.64, 8.30)	0.20	1 (4.6)	0.56 (0.23, 1.37)	0.21	4 (18.2)	0.63 (0.16, 2.47)	0.51
No	23 (12.2)	Ref.		12 (6.4)	Ref.		42 (22.2)	Ref.	
Does not use school restroom									
Yes	4 (44.4)	62.9 (2.62, 1508)	0.01	1 (11.1)	6.47 (0.40, 105)	0.19	2 (22.2)	0.43 (0.08, 2.39)	0.33
No	24 (11.9)	Ref.		12 (5.9)	Ref.		44 (21.8)	Ref.	
Hygiene lessons are not taught in school									
Yes	5 (26.3)	3.36 (0.61, 18.5)	0.16	2 (10.5)	6.22 (0.77, 49.9)	0.09	5 (26.3)	3.58 (0.92, 13.9)	0.07
No	23 (12)	Ref.		11 (5.7)	Ref.		41 (21.4)	Ref.	
Household level (self-reported)									
Number of adults									
1–2	13 (13.5)	Ref.		4 (4.2)	Ref.		22 (22.9)	Ref.	
3–4	7 (11.3)	0.69 (0.20, 2.38)	0.56	5 (8.1)	4.92 (0.91, 26.8)	0.07	15 (24.2)	0.46 (0.14, 1.51)	0.20
≥ 5	8 (15.1)	0.75 (0.16, 3.48)	0.71	4 (7.6)	3.12 (0.41, 23.4)	0.27	9 (17)	0.29 (0.06, 1.44)	0.13
Number of children									
1–2	6 (6.3)	Ref.		5 (5.2)	Ref.		26 (27.1)	Ref.	
3–4	11 (12.2)	0.96 (0.19, 4.82)	0.96	8 (8.9)	2.92 (0.49, 17.2)	0.24	15 (16.7)	0.37 (0.16, 0.87)	0.02
≥ 5	11 (45.8)	15.7 (1.79, 138)	0.01	0	n/a		4 (16.7)	0.15 (0.03, 0.80)	0.03

Duration (years) of residence in home									
0–4	7 (15.6)	Ref		3 (6.7)	Ref.		8 (17.8)	Ref.	
5–19	7 (8)	0.52 (0.07, 3.98)	0.53	4 (4.6)	0.41 (0.03, 6.18)	0.52	19 (21.6)	1.52 (0.57, 4.08)	0.40
≥ 20	14 (18)	1.41 (0.28, 7.22)	0.68	6 (7.7)	1.04 (0.22, 4.81)	0.97	19 (24.4)	4.21 (1.07, 16.7)	0.04
Does not eat a variety of food									
Yes	1 (7.7)	0.10 (0.01, 0.90)	0.04	2 (15.4)	5.56 (1.45, 21.4)	0.01	4 (30.8)	0.42 (0.06, 2.76)	0.37
No	27 (13.6)	Ref.		11 (5.6)	Ref.		42 (21.2)	Ref.	
Home WaSH (observed)									
No restroom inside home									
Yes	7 (35)	4.44 (0.73, 27.1)	0.11	2 (10)	6.31 (0.87, 45.9)	0.07	3 (15)	0.82 (0.26, 2.65)	0.74
No	20 (11.6)	Ref.		11 (6.4)	Ref.		35 (20.4)	Ref.	
Restroom is not clean									
Yes	15 (19.7)	0.71 (0.18, 2.86)	0.63	8 (10.5)	2 (0.24, 17)	0.53	9 (11.8)	0.46 (0.20, 1.07)	0.07
No	12 (10.3)	Ref.		5 (4.3)	Ref.		29 (25)	Ref.	
Restroom has no water									
Yes	3 (37.5)	1.09 (0.17, 7)	0.92	1 (12.5)	0.34 (0.01, 12.3)	0.56	0	n/a	
No	24 (13)	Ref.		12 (6.5)	Ref.		38 (20.7)		
Restroom has no handwashing basin									
Yes	15 (25)	14 (4.30, 46.2)	$p < 0.01$	4 (6.7)	1.80 (0.27, 12.2)	0.55	12 (20)	2.40 (0.94, 6.16)	0.07
No	11 (8.4)	Ref.		9 (6.9)	Ref.		26 (19.9)	Ref.	
Restroom is not well-lit									
Yes	12 (14.5)	0.15 (0.01, 1.51)	0.11	9 (10.8)	6.99 (1.20, 40.7)	0.03	14 (16.9)	1.51 (0.49, 4.64)	0.47
No	14 (13.2)	Ref.		4 (3.8)	Ref.		24 (22.6)	Ref.	

Restroom has no door lock									
Yes	15 (17.7)	1.73 (0.20, 15.2)	0.62	7 (8.2)	0.29 (0.06, 1.34)	0.11	12 (14.1)	0.43 (0.11, 1.70)	0.23
No	11 (10.4)	Ref.		6 (5.7)	Ref.		26 (24.5)	Ref.	
Restroom has signs of mould									
Yes	19 (19.4)	9.12 (1.89, 44)	0.01	7 (7.1)	2.18 (0.57, 8.42)	0.26	13 (13.3)	0.45 (0.28, 0.73)	p < 0.01
No	8 (8.5)	Ref.		6 (6.4)	Ref.		25 (26.6)	Ref.	
No garbage bin in or near restroom									
Yes	21 (18.4)	1.71 (0.34, 8.49)	0.51	8 (7)	0.51 (0.12, 2.28)	0.38	25 (21.9)	1.36 (0.60, 3.08)	0.47
No	6 (7.7)	Ref.		5 (6.4)	Ref.		13 (16.7)		

Note aOR, adjusted odds ratio; CI, confidence interval; Ref., reference group; WaSH, water, sanitation, and hygiene.
aORs were estimated by multiple logistic regression models. Variables of exposure included in models were: female, early-teenager (age 13–14 years old), does not eat three times per day, does not consider self to be “healthy”, had diarrhoea, is dehydrated (urine specific gravity ≥ 1.020), had helminth infection, does not wash hands in school, does not use school restroom, hygiene lessons are not taught in school, number of adults living in home, number of children living in home, duration (years) of residence in home, does not eat a variety of food at home, home has no indoor restroom, home restroom is not clean, home restroom has no water, home restroom has no handwashing basin, home restroom is not well-lit, home restroom has no door lock, home restroom has signs of mould, and no garbage can inside or nearby home restroom.

flights or car rides because they want to avoid using (what they perceived to be) unclean public restrooms.

Second was the improper maintenance of school restrooms as evidenced by the presence of flies, which was associated with under- and over-nutrition. Children may have avoided or not used the school restroom because they perceived them as negative, i.e., unclean, foul-smelling, dark, lacking privacy. Such negative perceptions were in line with findings from a survey of secondary school students and school restrooms in France. In that study, adolescents perceived restrooms negatively, avoided using the toilet, and complained of abdominal pain and urinary disorders (Hoarau et al., 2014). In our study, over half of students were not satisfied with school restrooms, with ~67% of students reporting that restrooms were not clean and more than half of students reporting that restrooms lacked privacy. Yet almost all students still used the restrooms. Thus, more investments are needed to improve and maintain the conditions of school restrooms in order to promote their use by children. We found that not using the school restroom was associated with stunting. This may be explained by the fact that children who did not use the toilet could become constipated. Consequences of chronic constipation include decreased appetite and stunted growth (Chao et al., 2008), which could explain the increased risk of undernutrition. Another possible explanation is that recurring enteric infections could alter the gastrointestinal tract, resulting in decreased nutrient absorption and stunted growth (Geurrant et al., 1983). Changes in the gastrointestinal tract that are relevant for stunted growth include: increased intestinal permeability, gut inflammation, bacterial translocation, and nutrient malabsorption (Owino et al., 2016). Another possible explanation is environmental enteric dysfunction, characterized by abnormalities in the small intestine that have been caused by chronic exposure to toxins found in unhygienic living conditions (Keusch et al., 2013). An unexpected result was the association between not using school restrooms and over-nutrition. One possible explanation is that this association was a proxy for family income and/or parental education, attention, and/or involvement. For example, the over-nourished children may have had parents with higher income or more education or involvement. As a result, these parents would not only provided their children more food, but also more instructions about proper hygiene. Also they may have advised their children not to use the school's "dirty" restrooms for fear of catching an infection.

Third was the lack of hygiene lessons, which was associated with stunting. Children may have had inadequate knowledge about preventing the spread of germs and, as a result, were not able or willing to practice health-promoting behaviours like handwashing and washing fruits and vegetables before consuming. A consequence of poor handwashing is infectious disease, which could result in malnutrition and impaired growth. While a study by Riiser and others (2020) showed how handwashing knowledge was linked to handwashing practices, a review by de Buck and others (2017) showed that there was no one clear handwashing promotion strategy that effectively increased handwashing practice.

Fourth was poor handwashing, which was associated with diarrhoea. Besides individual factors, poor handwashing may be attributed to the insufficient number of handwashing basins and the lack of water and soap in schools. Diarrhoea prevalence rates from our study were higher compared to those from previous studies in LMICs (Chard et al., 2019; Davis et al., 2014; Worrell et al., 2016). Children who did not wash their hands with soap and water after using the toilet were likely more exposed to faecal matter that causes gastrointestinal diseases like diarrhoea and helminth infection. Besides malnutrition, weight loss, and stunted growth, consequences of infection include school absence and increased risk of school dropout. These findings demonstrate the need to better promote hygiene education and handwashing, which decreases prevalence rates of diarrhoea by up to 47%, if done with soap (Curtis & Cairncross, 2003).

Where could these disease-causing WaSH deficiencies have come from? Besides the school environment and children's socioeconomic status, which was outside the scope of this study, we can examine health policy. Nearly all school principals reported that WaSH management policies were in place, yet the "poor" conditions of school restrooms begged the question of whether or not the policies were being effectively enforced. These findings may point to possible gaps in resource utilization, incident reporting, or factors outside of schools. We found that the maximum maintenance and other operating expenses budget was associated with decreased risks for diarrhoea, dehydration, and stunting. This demonstrates the need for further investments in schools in order to better protect children's health and prevent diseases.

2.4.2 Limitations

Our cross-sectional, observational study is limited by confounding and the inability to describe causality. Selection bias likely occurred when we allowed: one school to join our study after school personnel asked us directly if her school could participate; school personnel to select which class section(s) would be surveyed; one school to join our study where we conducted pilot testing of our survey instruments. A possible impact of allowing the pre-tested school to join our study was that some children may have been aware of our survey, leading some to provide biased answers on the questionnaire that they perceived to be "desirable". Allowing school personnel to select the class sections to be surveyed likely resulted in an over-sampling of top-academically-performing children and an under-representation of poor-academically-performing children, who may have also belonged to families of the lowest SES and who had greater exposures to inadequate WaSH and other disease risk factors.

Self-report is prone to bias, e.g., recall bias, which may have occurred when we used self-reported outcome measures for diarrhoea without corroborating with medical records. Self-report may be influenced by children's perceptions about what is "desirable" and "undesirable" according to social/cultural norms, feelings of shame, and fears about being punished.

A disadvantage of using U_{sg} is that measurements depend on the number and size of particles contained in the urine (Baron et al., 2015). Evidence about the reliability of urine test strips, compared with refractometry, to measure U_{sg} is mixed (de Buys Roessingh et al., 2001; Gounden & Newall, 1983). A disadvantage of using urine test strips is that the accuracy of measurements may decrease as urine alkalinity increases (pH > 7) (Adams, 1983). We did not triangulate dehydration measurements with physical symptoms of dehydration or children's report of thirst.

There was a one-year time lag between our measurement of children's health outcomes and water quality testing, and we measured water quality only once, so, we could not assess seasonality/temporal variability. Another risk of bias was the large number of children excluded from data analysis due to missing responses. After examining missing data, however, we found no statistically significant difference between children who were missing data and children who were not missing data for key outcomes. Therefore, we concluded that data were missing at random (MAR), though not missing completely at random (MCAR).

We assessed a large number of risk factors, some of which may be unrelated to each other; it is possible that associations have arisen by chance. We also simultaneously assessed multiple outcomes, so, there could have been a possible multiple comparisons effect (Lindquist & Mejia, 2015).

2.4.3 Strengths

Our study provided new information about using children's dehydration, measured via U_{sg}, as an indicator of schools' water insecurity, which we confirmed with children's self-report and researchers' observations. These data are helpful for interpreting study findings about children's dehydration, which could negatively impact children's cognitive performance, e.g., by decreasing short-term memory (Bar-David et al., 2005). Previous studies (Edmonds & Jeffes, 2009) have examined dehydration's negative impact on children's cognitive performance but few have used biospecimens to measure dehydration. Findings from our study address this data gap.

2.4.4 Generalizability

The generalizability, or external validity, of our study was supported by: multistage cluster sampling of students in grades five, six, seven, nine, and 10 (ages ~10-15 years old) from 15 public schools in three cities of Metro Manila; high participation rate from a large study sample; analyses of risk factors for diarrhoea, malnutrition, and dehydration while taking into account variance in prevalence rates across different schools. Adherence to study protocols, rigorous investigation, and standardized data collection and reporting increase our confidence that our study findings may be generalizable to other urban poor populations living in areas with comparable weather and school WaSH conditions. However, due to our study's cross-sectional, observational design and limited capacity to control for confounding and describe cause and effect, our study findings may be applicable only to specific locations in terms of disease prevalence and environmental risk factors. Our findings need to be verified by longitudinal studies with larger samples before attempting to generalize them to diverse populations or settings in other LMICs.

2.4.5 Implications for policy, practice, and future research

Before we make any recommendations, we acknowledge that our cross-sectional study neither measured changes in diarrhoea episodes and contributing factors over time, nor did it measure changes during different seasons. Thus, readers should consider that these study results provide no evidence in terms of causality, and that our below recommendations were based on suggested, rather than causal, associations.

Due to the complexity of school WaSH management, a comprehensive, context-specific school WaSH strategy is recommended instead of a one-size-fits-all approach. Possible solutions could be interventions that facilitate the implementation and enforcement of school WaSH policies. For example, a school administrator may be designated to lead a small team of “super-users” (school personnel) to ensure restrooms are being cleaned and maintained, provide hygiene lessons, and promote group handwashing among students. Also, a group of student volunteers may be named as “restroom monitors” in each school to ensure that WaSH facilities are properly used and kept clean, and to remind their fellow students to wash their hands after using the toilet/urinal and before eating. Funding should be used to increase the number of clean and functional WaSH facilities, maintain them, and promote their proper use by schoolchildren.

Future research should explore other methods of assessing diarrhoea, although our findings indicate that self-report should not necessarily be dismissed. We identified an association between diarrhoea and stunting, which is consistent with previous studies (Schilling et al., 2017). Future studies should explore school WaSH facilities and students’ diarrhoea prevalence in other LMICs or upper-middle-income countries located in the tropics, e.g., Vietnam and Thailand, where temperatures and rainfall are as high as in the Philippines, but the rates of diarrhoea-related mortality are lower.

Research is needed to test WaSH interventions aimed at improving children’s nutrition status by preventing diarrhoea. This could be achieved by reducing children’s exposure to enteropathogens in schools’ WaSH facilities and increasing children’s health literacy and promoting handwashing. Greater emphasis should be placed on improving water quality in settings where faecal water contamination is prevalent and causing disease. Evidence about the effectiveness of WaSH interventions in decreasing risks of infectious diseases is mixed (Ashraf et al., 2020; Chard et al., 2019; Pickering et al., 2019; Trinies et al., 2016). Research is needed to clarify the relationship between WaSH and infectious diseases.

2.5 Conclusions

By linking schools' WaSH facilities and students' handwashing and dissatisfaction with and avoidance of school restrooms with disease prevalence, we point to an urgent need for comprehensive school-based WaSH interventions, especially those that promote proper handwashing. However, the associations we found between school WaSH and children's health may be explained more by school location than school WaSH. Due to the cross-sectional design of our study, we were not able to assess causation. This should be considered when interpreting our study results. Future studies that use, for example, a cluster-randomised controlled design, are needed to assess causation between exposure to inadequate school WaSH and children's health outcomes. More research is needed to understand the complex relationship between schools' WaSH facilities and children's hygiene practices and diarrhoea, malnutrition, and dehydration in the Philippines. Elsewhere in the Global South, where the COVID-19 pandemic has forced schools to close and increased food and water security, new WaSH strategies are needed. Our study findings could help promote school WaSH to protect children from faecal-contaminated water that drives disease risks, while ensuring that children have access to the benefits of water security: good health, hygiene, and hydration.

References

1. Adams, L. J. (1983). Evaluation of Ames Multistix-SG for urine specific gravity versus refractometer specific gravity. *American Journal of Clinical Pathology*, *80*(6), 871–873. https://doi.org/10.1093/ajcp/80.6.871
2. Armstrong, L. E., Maresh, C. M., Castellani, J. W., Bergeron, M. F., Kenefick, R. W., LaGasse, K. E., & Riebe, D. (1994). Urinary indices of hydration status. *International Journal of Sport Nutrition*, *4*(3), 265–279. https://doi.org/10.1123/ijsn.4.3.265
3. Ashraf, S., Islam, M., Unicomb, L., Rahman, M., Winch, P. J., Arnold, B. F., Benjamin-Chung, J., Ram, P. K., Colford, J. M., & Luby, S. P. (2020). Effect of Improved Water

Quality, Sanitation, Hygiene and Nutrition Interventions on Respiratory Illness in Young Children in Rural Bangladesh: A Multi-Arm Cluster-Randomized Controlled Trial. *The American journal of tropical medicine and hygiene*, *102*(5), 1124–1130. https://doi.org/10.4269/ajtmh.19-0769

4. Bar-David, Y., Urkin, J., & Kozminsky, E. (2005). The effect of voluntary dehydration on cognitive functions of elementary school children. *Acta Paediatrica (Oslo, Norway: 1992)*, *94*(11), 1667–1673. https://doi.org/10.1080/08035250500254670
5. Baron, S., Courbebaisse, M., Lepicard, E. M., & Friedlander, G. (2015). Assessment of hydration status in a large population. *The British Journal of Nutrition*, *113*(1), 147–158. https://doi.org/10.1017/S0007114514003213
6. Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., Onis, M. de, Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., & Uauy, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X
7. Chao, H.-C., Chen, S.-Y., Chen, C.-C., Chang, K.-W., Kong, M.-S., Lai, M.-W., & Chiu, C.-H. (2008). The Impact of Constipation on Growth in Children. *Pediatric Research*, *64*(3), 308–311. https://doi.org/10.1203/PDR.0b013e31817995aa
8. Chard, A. N., Garn, J. V., Chang, H. H., Clasen, T., & Freeman, M. C. (2019). Impact of a school-based water, sanitation, and hygiene intervention on school absence, diarrhoea, respiratory infection, and soil-transmitted helminths: Results from the WASH HELPS cluster-randomized trial. *Journal of Global Health*, *9*(2), 020402. https://doi.org/10.7189/jogh.09.020402
9. Curtis, V., & Cairncross, S. (2003). Effect of washing hands with soap on diarrhoea risk in the community: A systematic review. *The Lancet Infectious Diseases*, *3*(5), 275–281. https://doi.org/10.1016/S1473-3099(03)00606-6
10. Davis, S. M., Worrell, C. M., Wiegand, R. E., Odero, K. O., Suchdev, P. S., Ruth, L. J., Lopez, G., Cosmas, L., Neatherlin, J., Njenga, S. M., Montgomery, J. M., & Fox, L. M. (2014). Soil-Transmitted Helminths in Pre-School-Aged and School-Aged Children in an Urban Slum: A Cross-Sectional Study of Prevalence, Distribution, and Associated Exposures. *The American Journal of Tropical Medicine and Hygiene*, *91*(5), 1002–1010. https://doi.org/10.4269/ajtmh.14-0060

11. de Buck, E., Van Remoortel, H., Hannes, K., Govender, T., Naidoo, S., Avau, B., Vande Veegaete, A., Musekiwa, A., & Lutje, V. (2017). Promoting handwashing and sanitation behaviour change in low- and middle-income countries: A mixed-method systematic review, 3ie Systematic Review Summary 10, London: International Initiative for Impact Evaluation (3ie). Retrieved on April 22, 2022 from https://www.3ieimpact.org/evidence-hub/publications/systematic-reviews/promoting-handwashing-and-sanitation-behaviour-change
12. de Buys Roessingh, A. S., Drukker, A., & Guignard, J. P. (2001). Dipstick measurements of urine specific gravity are unreliable. *Archives of Disease in Childhood*, *85*(2), 155–157. https://doi.org/10.1136/adc.85.2.155
13. de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization*, *85*(9), 660–667. https://doi.org/10.2471/blt.07.043497
14. Development Initiatives. (2018). *2018 Global Nutrition Report: Shining a light to spur action on nutrition*. https://globalnutritionreport.org/reports/global-nutrition-report-2018/ Accessed 26 January 2022.
15. Edmonds, C. J., & Jeffes, B. (2009). Does having a drink help you think? 6-7-Year-old children show improvements in cognitive performance from baseline to test after having a drink of water. *Appetite*, *53*(3), 469–472. https://doi.org/10.1016/j.appet.2009.10.002
16. Ellis, A., Haver, J., Villasenor, J., Parawan, A., Venkatesh, M., Freeman, M. C., & Caruso, B. A. (2016). WASH challenges to girls' menstrual hygiene management in Metro Manila, Masbate, and South Central Mindanao, Philippines. *Waterlines*, *35*(3), 306–323. https://doi.org/10.3362/1756-3488.2016.022
17. Food and Agriculture Organization of the United Nations (Ed.). (2013). The state of food and agriculture. Food systems for better nutrition. Rome: Food and Agriculture Organization of the United Nations; 2013: 99. http://www.fao.org/3/i3300e/i3300e00.pdf . Accessed 26 January 2022.
18. Gounden, D., & Newall, R. G. (1983). Urine specific gravity measurements: Comparison of a new reagent strip method with existing methodologies, as applied to the water

concentration/dilution tests. *Current Medical Research and Opinion*, *8*(6), 375–381. https://doi.org/10.1185/03007998309111742

19. Guerrant, R. L., Kirchhoff, L. V., Shields, D. S., Nations, M. K., Leslie, J., de Sousa, M. A., Araujo, J. G., Correia, L. L., Sauer, K. T., & McClelland, K. E. (1983). Prospective study of diarrheal illnesses in northeastern Brazil: patterns of disease, nutritional impact, etiologies, and risk factors. The Journal of infectious diseases, 148(6), 986–997. https://doi.org/10.1093/infdis/148.6.986
20. Hoarau, B., Vercherin, P., & Bois, C. (2014). [School bathrooms: Children's perceptions and prevalence of gastrointestinal and urinary disorders, a survey in 3 secondary schools near Saint-Etienne]. *Sante Publique (Vandoeuvre-Les-Nancy, France)*, *26*(4), 421–431.
21. Jin, H., Wang, B., Fang, Z., Duan, Z., Gao, Q., Liu, N., Zhang, L., Qian, Y., Gong, S., Zhu, Q., Shen, X., & Wu, Q. (2011). Hospital-based study of the economic burden associated with rotavirus diarrhoea in eastern China. *Vaccine*, *29*(44), 7801–7806. https://doi.org/10.1016/j.vaccine.2011.07.104
22. Katsuno, C., Gregorio, E. R., Lomboy, M. F. T. C., Nonaka, D., Hernandez, P. M. R., Estrada, C. A. M., Pimentel, J. M. T., Bernadas, R. M. G. C., & Kobayashi, J. (2019). Quality of public school toilets and the frequency of changing sanitary napkins among students in public secondary schools in the City of Manila, Philippines. *Tropical Medicine and Health*, *47*(1), 5. https://doi.org/10.1186/s41182-018-0131-8
23. Keusch, G. T., Rosenberg, I. H., Denno, D. M., Duggan, C., Guerrant, R. L., Lavery, J. V., Tarr, P. I., Ward, H. D., Black, R. E., Nataro, J. P., Ryan, E. T., Bhutta, Z. A., Coovadia, H., Lima, A., Ramakrishna, B., Zaidi, A. K., Burgess, D. C., & Brewer, T. (2013). Implications of acquired environmental enteric dysfunction for growth and stunting in infants and children living in low- and middle-income countries. *Food and nutrition bulletin*, *34*(3), 357–364. https://doi.org/10.1177/156482651303400308
24. Lindquist, M. A., & Mejia, A. (2015). Zen and the art of multiple comparisons. *Psychosomatic Medicine*, *77*(2), 114–125. https://doi.org/10.1097/PSY.0000000000000148
25. Naghavi, M., & et al. (2017). *Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: A systematic analysis for the Global Burden of Disease*

Study 2016—The Lancet. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32152-9/fulltext

26. Ngabo, F., Mvundura, M., Gazley, L., Gatera, M., Rugambwa, C., Kayonga, E., Tuyishime, Y., Niyibaho, J., Mwenda, J. M., Donnen, P., Lepage, P., Binagwaho, A., & Atherly, D. (2016). The Economic Burden Attributable to a Child's Inpatient Admission for Diarrhoeal Disease in Rwanda. *PLOS ONE*, *11*(2), e0149805. https://doi.org/10.1371/journal.pone.0149805
27. Owino, V., Ahmed, T., Freemark, M., Kelly, P., Loy, A., Manary, M., & Loechl, C. (2016). Environmental Enteric Dysfunction and Growth Failure/Stunting in Global Child Health. *Pediatrics*, *138*(6), e20160641. https://doi.org/10.1542/peds.2016-0641
28. Pagana, K. D., Pagana, T. J., & Pagana, T. N. (2015). *Mosby's diagnostic and laboratory test reference.* 12th Ed.; Elsevier, Inc: St. Louis, MO, USA. p. 671–672, 952, 956–957, ISBN: 978-0-323-22576-2.
29. Philippines Department of Education. (2019a). *Elementary and junior and senior high school enrolment, school years 2014-2019. [Data set].*
30. Philippines Department of Education. (2019b). *Number of public classroom in elementary and junior high school, Enrolment school year 2018-2019. [Data set].*
31. Philippines Department of Education. (2019c). *Public schools MOOE allocation, fiscal years (FYs) 2015-2019. [Data set].*
32. Philippines Department of Health. (1998). *Implementing rules of and regulations on chapter VI, "School sanitation and health services", of the code on sanitation of the Philippines (P.D. 856).* https://www.doh.gov.ph/sites/default/files/publications/Chapter_6_School_Sanitation_and_Health_Services.pdf Accessed 7 July 2021.
33. Philippines Department of Health. (2017). *Philippine National Standards for Drinking Water of 2017. Administrative Order 2017-0010*. https://dmas.doh.gov.ph:8083/Rest/GetFile?id=337128 Accessed 26 January 2022.
34. Philippines Department of Health. (2018). *Field Health Services Information System Annual Report 2018*. https://doh.gov.ph/sites/default/files/publications/FHSIS_Annual_2018_Final.pdf Accessed 26 January 2022.

35. Philippine Statistics Authority. (2021). *2021 Philippines in figures*. https://psa.gov.ph/sites/default/files/2021_pif_final%20%281%29.pdf Accessed 10 March 2022.
36. Pickering, A. J., Null, C., Winch, P. J., Mangwadu, G., Arnold, B. F., Prendergast, A. J., Njenga, S. M., Rahman, M., Ntozini, R., Benjamin-Chung, J., Stewart, C. P., Huda, T., Moulton, L. H., Colford, J. M., Jr, Luby, S. P., & Humphrey, J. H. (2019). The WASH Benefits and SHINE trials: interpretation of WASH intervention effects on linear growth and diarrhoea. *The Lancet. Global health*, *7*(8), e1139–e1146. https://doi.org/10.1016/S2214-109X(19)30268-2
37. Prüss-Ustün, A., Wolf, J., Bartram, J., Clasen, T., Cumming, O., Freeman, M. C., Gordon, B., Hunter, P. R., Medlicott, K., & Johnston, R. (2019). Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low- and middle-income countries. *International Journal of Hygiene and Environmental Health*, *222*(5), 765–777. https://doi.org/10.1016/j.ijheh.2019.05.004
38. Riiser, K., Helseth, S., Haraldstad, K., Torbjørnsen, A., & Richardsen, K. R. (2020). Adolescents' health literacy, health protective measures, and health-related quality of life during the Covid-19 pandemic. *PLOS ONE*, *15*(8), e0238161. https://doi.org/10.1371/journal.pone.0238161
39. Rivera, M. M. (1996). *Practical Guide to Thesis and Dissertation Writing*. Katha Pub.130.
40. Save the Children Philippines. (2016). *Cost of Hunger: Philippines. The Economic Impact of Child Undernutrition on Education and Productivity in the Philippines*. https://resourcecentre.savethechildren.net/node/12557/pdf/save-the-children-cost-of-hunger-philippines-2016.pdf Accessed 26 January 2022.
41. Schilling, K. A., Omore, R., Derado, G., Ayers, T., Ochieng, J. B., Farag, T. H., Nasrin, D., Panchalingam, S., Nataro, J. P., Kotloff, K. L., Levine, M. M., Oundo, J., Parsons, M. B., Bopp, C., Laserson, K., Stauber, C. E., Rothenberg, R., Breiman, R. F., O'Reilly, C. E., & Mintz, E. D. (2017). Factors Associated with the Duration of Moderate-to-Severe Diarrhoea among Children in Rural Western Kenya Enrolled in the Global Enteric Multicenter Study, 2008–2012. *The American Journal of Tropical Medicine and Hygiene*, *97*(1), 248–258. https://doi.org/10.4269/ajtmh.16-0898

42. Trinies, V., Garn, J. V., Chang, H. H., & Freeman, M. C. (2016). The Impact of a School-Based Water, Sanitation, and Hygiene Program on Absenteeism, Diarrhea, and Respiratory Infection: A Matched-Control Trial in Mali. *The American journal of tropical medicine and hygiene*, *94*(6), 1418–1425. https://doi.org/10.4269/ajtmh.15-0757
43. Troeger, C., Blacker, B. F., Khalil, I. A., Rao, P. C., Cao, S., Zimsen, S. R., Albertson, S. B., Stanaway, J. D., Deshpande, A., Abebe, Z., Alvis-Guzman, N., Amare, A. T., Asgedom, S. W., Anteneh, Z. A., Antonio, C. A. T., Aremu, O., Asfaw, E. T., Atey, T. M., Atique, S., … Reiner, R. C. (2018). Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: A systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Infectious Diseases*, *18*(11), 1211–1228. https://doi.org/10.1016/S1473-3099(18)30362-1
44. United Nations International Children's Emergency Fund (UNICEF). (2018). *The Economic Consequences of Undernutrition in the Philippines: A Damage Assessment Report (DAR)*. https://childrightsnetwork.ph/download/the-economic-consequences-of-undernutrition-in-the-philippines-pdf/ Accessed 6 July 2021.
45. Vargas, M. (2019). *Nutritional Status of Filipino School Children (6-10 years old), 2018 Expanded National Nutrition Survey (ENNS). Department of Science and Technology Food & Nutrition Research Institute (DOST-FNRI). [Electronic source] Presented in 2019 National Nutrition Summit*. https://www.fnri.dost.gov.ph/images//sources/eNNS2018/Pre-school_and_School-Children.pdf Accessed 15 June 2020.
46. WHO. (2017b). *Diarrhoeal disease*. https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease Accessed 26 January 2022.
47. WHO. (2007a). *Growth reference 5-19 years—BMI-for-age (5-19 years)*. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age Accessed 26 January 2022.
48. WHO. (2007b). *Growth reference 5-19 years—Height-for-age (5-19 years)*. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/height-for-age Accessed 26 January 2022.

49. WHO. (2017a). *The Double Burden of Malnutrition. Policy Brief*. https://apps.who.int/iris/bitstream/handle/10665/255413/WHO-NMH-NHD-17.3-eng.pdf?ua=1 Accessed 26 January 2022.
50. WHO, Adams, J., Bartram, J., Chartier, Y., & Sims, J. (2009). *Water, sanitation and hygiene standards for schools in low-cost settings*. https://www.who.int/water_sanitation_health/publications/wash_standards_school.pdf?ua=1 Accessed 26 January 2022.
51. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. (2010). *Progress on sanitation and drinking-water: 2010 update*. World Health Organization. https://apps.who.int/iris/handle/10665/44272 Accessed 26 January 2022.
52. Worrell, C. M., Wiegand, R. E., Davis, S. M., Odero, K. O., Blackstock, A., Cuéllar, V. M., Njenga, S. M., Montgomery, J. M., Roy, S. L., & Fox, L. M. (2016). A Cross-Sectional Study of Water, Sanitation, and Hygiene-Related Risk Factors for Soil-Transmitted Helminth Infection in Urban School- and Preschool-Aged Children in Kibera, Nairobi. *PLOS ONE*, *11*(3), e0150744. https://doi.org/10.1371/journal.pone.0150744

2.A Supplementary materials

https://ars.els-cdn.com/content/image/1-s2.0-S0048969722029795-mmc1.pdf

Contents

Table S2.1 Questions from children's questionnaire.

Number	Question
1; 2	ID; What is today's date?
3	What is your birth date?
4	What is your telephone / cellphone number?
5	What is your complete address?
6	What is your age in years?
7	What is your grade level?
8	What is your sex?
9	What is the name of your school?
10	Have you been attending this school for at least 6 months?
11	Have you NOT needed to miss school a lot in the past year because of any health problems?
12	Are you satisfied ("happy") with the school toilets?
13	Do you use the school toilets every day if needed?
14	Do you NOT avoid using the school toilet (and just wait until you go home to go to the bathroom)?
15	Are toilets easily accessible (easy to get to or not too far away)?
16	Are the toilet rooms easy to use for persons with disabilities (with ramps/stairs/holder, spacious)?
17	Are there RARELY long lines to use the school toilet?
18	Are there enough toilets at your school?
19	Is toilet paper available all the time?
20	Are the toilet rooms clean?
21	Do you think that there is enough privacy in the toilet cabins/in front of the urinals?
22	Can pupils complain to school staff about a bad situation in the school toilet?
23	Does the school staff take any action to fix the problem when pupils complain?
24	Do you wash your hands at school?
25	Is there a hand wash area in your school?
26	Are you satisfied ("happy") with the hand wash area at school?
27	Is there always soap available?
28	Is there always water available for bathroom use?
29	Is there a towel or paper to dry your hands?
30	Are the hand wash areas clean at school?
31	Do you use soap for washing hands at school?
32	Do they teach good hygiene practices at school?
33	Do you eat at least 3 meals every day?
34	Do you eat lunch at school?
35	Do you RARELY feel hungry?
36	Do you RARELY feel so hungry that you cannot concentrate at school?
37	Do you RARELY feel so hungry that you cannot fall asleep?
38	Do you feel healthy overall?

39	Have you NEVER had intestinal worms?
40	In the last 6 months, were you NEVER hospitalized?
41	In the last 6 months, have you NOT had surgery?
42	How many times have you had diarrhoea in the last month?
43	How many people in your house also had diarrhoea in the last month?
44	How many days have you been hospitalized due to diarrhoea?

Table S2.2 Operational definitions.

Indicator		**Definition**	**Source**
Malnutrition			
Stunting	Stunted	HAZ[a] < -2	(de Onis et al., 2007; WHO, 2007b)
Undernutrition	Underweight ("thin")	-3 < BAZ[a,b] < -2	(de Onis et al., 2007; WHO, 2007a)
	Wasted ("severely thin")	BAZ < -3	(de Onis et al., 2007; WHO, 2007a)
Over-nutrition	Overweight	1 < BAZ < 2	(de Onis et al., 2007; WHO, 2007a)
	Obese	BAZ > 2	(de Onis et al., 2007; WHO, 2007a)
WaSH adequacy			
Sanitation			
Improved	Facility that hygienically separates human excreta from human contact	e.g. flush toilet, pour-flush latrines, ventilated improved pit latrines and pit latrines with a slab or covered pit	(WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2010)
Unimproved	Facility that does not hygienically separates human excreta from human contact	e.g. pit latrines without slabs or platforms or open pit, hanging latrines, bucket latrines, open defecation, disposal of human faeces with other forms of solid waste	(WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2010)
Male student-to-toilet ratio	Less than 50 students	1 toilet, 1 urinal, 1 handwashing basin	(Philippines Department of Health, 1998)
	50 or more students	2 toilets, 1 urinal, 2 handwashing basins	(Philippines Department of Health, 1998)
	For each additional 100 students	1 toilet, 1 urinal, 1 handwashing basin	(Philippines Department of Health, 1998)
Female student-to-toilet ratio	Less than 30 students	1 toilet, 1 handwashing basin	(Philippines Department of Health, 1998)
	30–100 students	2 toilets, 2 handwashing basins	(Philippines Department of Health, 1998)
	For each additional 50 students	1 toilet	(Philippines Department of Health, 1998)
	For each additional 100 students	1 handwashing basin	(Philippines Department of Health, 1998)
Male student-to-toilet ratio	50 students	1 toilet, 1 urinal (or 50 cm of urinal wall)	(Philippines Department of Health, 2017)

Female student-to-toilet ratio	25 students	1 toilet	(Philippines Department of Health, 2017)
Student-to-handwashing (handwashing) basin ratio	N/A	N/A	No WHO guidelines available
Male student-to-toilet ratio	Low	≤ 50:1	Category used in present study
	Medium	51:1–100:1	Category used in present study
	High	≥ 101:1	Category used in present study
Female student-to-toilet ratio	Low	≤ 50:1	Category used in present study
	Medium	51:1–100:1	Category used in present study
	High	≥ 101:1	Category used in present study
Student-to-handwashing basin ratio	Low	≤ 50:1	Category used in present study
	Medium	51:1–150:1	Category used in present study
	High	≥ 151:1	Category used in present study

Note BAZ, body mass index-for-age Z-score; BMI, body mass index;; HAZ, height-for-age Z-score; kg, kilogram; m, meter; N/A, not applicable; UNICEF, United Nations International Children's Emergency Fund; WaSH, water, sanitation, and hygiene; WHO, World Health Organization.

[a]HAZ and BAZ estimates were obtained using WHO AnthroPlus software (WHO, Geneva, Switzerland). Estimates are based on the WHO Reference 2007 for children 5-19 years old.

[b]BAZ based on BMI, which is calculated by weight (kg) / [height (m)]^2.

Table S2.3 Results of water quality testing in schools and homes (N=60).

	Schools			Homes			Normal range	Ref.
	valid n	n	% (95% CI)	valid n	n	% (95% CI)		
% of schools whose water had coliform bacteria [a]	11	4	36.4 (10.9, 69.2)	7	3	42.9 (9.9, 81.6)		
% of schools whose water had *E.coli* [a]	12	3	25.0 (5.5, 57.2)	7	4	57.1 (18.4, 90.1)		
Number of water samples with coliform bacteria	17	7	41.2 (18.4, 67.1)	14	6	42.9 (17.7, 71.7)		
Number of water samples with *E.coli*	20	3	15 (3.2, 37.9)	14	4	28.6 (8.4, 58.1)		
Air temperature (°C), median (IQR)		32 (30.5, 34.0)			33 (32, 34.5)		24, 31	
Water temperature (°C), median (IQR)		30 (27.0, 32.5)			28.5 (28, 29.4)		26.4, 28.3	
BOD, median (IQR)		0.63 (0.31, 1.61)			0.88 (0.52, 1.81)		< 5 mg/L	EPA[b]
DO, median (IQR)		7.35 (6.33, 8.37)			7.67 (7.37, 8.50)		7.81, 8.09 mg/L	EPA[b]
Nitrate[c], median (IQR)		0.10 (0.05, 0.13)			0.10 (0.08, 0.11)		< 50 mg/L	DOH[d]
pH, median (IQR)		7.45 (7.29, 7.63)			7.38 (7.33, 7.61)		6.5, 8.5	DOH[d]
TDS , median (IQR)		81 (60, 106)			68 (62, 102)		< 600 mg/L	DOH[d]
Turbidity, median (IQR)		0.16 (0.01, 1.19)			0.22 (0.11, 0.32)		< 5 NTU	DOH[d]

BOD, biological oxygen demand; °C, degree Celsius; CI, confidence interval; DO, dissolved oxygen; DOH, Philippines Department of Health; E.coli, Escherichia coli; EPA, United States Environmental Protection Agency; IQR, interquartile range; NTU, nephelometric turbidity units; Ref., reference; TDS, total dissolved solids; WHO, World Health Organization.

We collected water samples from a subset of consenting households, located in or nearby the neighbourhood of 11 of the study schools, to characterize the water quality in the community. We conducted water sampling in April 2018, after the intervention phase of our larger research project, "WaSH in Metro Manila Schools". We have reported the study protocols of the intervention study (Sangalang et al., 2021). We collected water per protocol in clean sample containers with lids. We labelled water samples per protocol and, depending on the water quality test we desired, we stored water samples in insulated cool boxes for transport to the laboratory. We used calibrated digital field meters and specialized laboratory equipment to assess water's physical and chemical properties: BOD, DO, nitrates, pH, temperature, TDS, and turbidity. We analysed samples, using an Extech Instruments (model DO700) (Extech Instruments Corp., Waltham, MA, U.S.A.) water quality meter, at the Institute of Environmental Science and Meteorology at the University of the Philippines Diliman. Other water samples were prepared for transfer to a nearby DOH-accredited water testing laboratory for analysis. We outsourced these water quality tests because our local laboratory had insufficient equipment, materials, and space for analyses or storage. Results from schools and homes were compared to assess if drinking water was contaminated due to unsafe water storage or hygiene practices. We calculated % by dividing the number affected (n) by the total number available (valid n). Then we multiplied the answer by 100 to get a proportion. We referred to the Philippine National Standards for Drinking Water of 2017. No health-related guideline values from the Philippines or the WHO were available for two parameters (biological oxygen demand [BOD] and dissolved oxygen [DO]). Thus, we used guidelines from the United States Environmental Protection Agency (EPA). For DO, the recommended values were estimated by using an EPA-provided reference table; estimations were dependent on temperature and salinity.

[a]We assessed water for faecal contamination as evidenced by coliform bacteria and E. coli. We used a pipette to transfer 1 mL of water to 3M™ Petrifilm™ E. coli/Coliform Count Plates. We photographed plates after 24 hours and 48 hours, and then we manually counted the number of colonies on the plates.

[b]Source: EPA. (2006). Voluntary Estuary Monitoring Manual. Chapter 9: Dissolved Oxygen and Biochemical Oxygen Demand. Retrieved July 29, 2021, from https://www.epa.gov/sites/production/files/2015-09/documents/2009_03_13_estuaries_monitor_chap9.pdf

[c]Nitrate as NO3-.

[d]Source: DOH. (2017). Philippine National Standards for Drinking Water of 2017. Administrative Order 2017-0010. Retrieved July 29, 2021, from https://dmas.doh.gov.ph:8083/Rest/GetFile?id=337128

Table S2.4 Equations for logistic regression models.

We analysed the main sample with two logistic regression models: one model (A) for diarrhoea and one model (B) for malnutrition, i.e. stunting only, undernutrition only, and overnutrition only. To measure the association between outcomes and exposures, we used the following model.

$\log it(\pi_{abcde}) = \beta_1 San_b \times \beta_2 San_c + Xc_{abc} + \Delta s_b + Ks_d + \zeta_m$

where

- π_{abcde} = dichotomous outcome for child *a* in school *b* in cluster *c* in survey *d* in matched group *e*
- San_b = whether school has any sanitation
- San_c = level of sanitation in school
- C_{abc} = vector of child characteristics
- S_b = vector of school characteristics
- S_d = vector of survey characteristics
- ζ_m = random intercept for matched group *m* that is assumed to be normally distributed with a mean of 0

We analysed the subsample with two logistic regression models: one model (C) for diarrhoea and one model (D) for malnutrition, i.e. stunting only, undernutrition only, and overnutrition only. To measure the association between outcomes and exposures, we used the following model.

$\log it(\pi_{abcdefg}) = \beta_1 San_b \times \beta_2 San_c + Xc_{abc} + \Delta s_b + Ks_d + F_f + H_g + \zeta_m$

where

- π_{abcde} = dichotomous outcome for child *a* in school *b* in cluster *c* in survey *d* in matched group *e* from family *f* in home *g*
- San_b = whether school has any sanitation
- San_c = level of sanitation in school
- C_{abc} = vector of child characteristics
- S_b = vector of school characteristics
- S_d = vector of survey characteristics
- F_f = vector of family characteristics
- H_g = vector of home characteristics
- ζ_m = random intercept for matched group *m* that is assumed to be normally distributed with a mean of 0

Table S2.5 Schools included in survey by location of "barangay" (smallest government unit) (N=15).

Barangay	Schools (%)	Students (%)
Location adjacent to		
River or estuary	3 (20)	345 (22.1)
Coastline or bay	6 (40)	638 (41)
Highway or primary road	6 (40)	575 (36.9)
All areas	15 (100)	1,558 (100)

Table S2.6 Prevalence of children's health outcomes by sex and age group

Outcome	All (n = 1,558)			Male (n = 697)			Female (n = 861)		
	valid n[a]	n	% (95% CI)	valid n	n	% (95% CI)	valid n	n	% (95% CI)
Diarrhoea	1478	421	28.5 (26.2, 30.9)	657	201	30.6 (27.1, 34.3)	821	220	26.8 (23.8, 30)
Stunting[b]	1497	227	15.2 (13.4, 17.1)	667	102	15.3 (12.6, 18.3)	830	125	15.1 (12.7, 17.7)
Undernutrition[b]	1478	127	8.6 (7.2, 10.1)	659	73	11.1 (8.8, 13.7)	819	54	6.6 (5, 8.5)
Over-nutrition[b]	1478	321	21.7 (19.6, 23.9)	659	160	24.3 (21.1, 27.7)	819	161	19.7 (17, 22.5)
Any dehydration[c]	1405	956	68 (65.5, 70.5)	629	432	68.7 (64.9, 72.3)	776	524	67.5 (64.1, 70.8)
Mild dehydration[c]	1405	214	15.2 (13.4, 17.2)	629	103	16.4 (13.6, 19.5)	776	111	14.3 (11.9, 17)
Moderate dehydration[c]	1405	457	32.5 (30.1, 35)	629	193	30.7 (27.1, 34.5)	776	264	34 (30.7, 37.5)
Severe dehydration[c]	1405	285	20.3 (18.2, 22.5)	629	136	21.6 (18.5, 25)	776	149	19.2 (16.5, 22.2)

Outcome	Child[d] (n = 1039)			Teenager[e] (n = 519)		
	valid n	n	% (95% CI)	valid n	n	% (95% CI)
Diarrhoea	998	296	29.7 (26.8, 32.6)	480	125	26 (22.2, 30.2)
Stunting	988	136	13.6 (11.6, 15.9)	508	91	17.9 (14.7, 21.5)
Undernutrition	974	70	7.2 (5.6, 9)	503	57	11.3 (8.7, 14.4)
Over-nutrition	974	245	25.2 (22.5, 28)	503	76	15.1 (12.1, 18.5)
Any dehydration[c]	913	602	65.9 (62.8, 69)	491	354	72.1 (67.9, 76)
Mild dehydration[c]	913	147	16.1 (13.8, 18.6)	491	67	13.6 (10.7, 17)
Moderate dehydration[c]	913	303	33.2 (30.1, 36.3)	491	154	31.4 (27.3, 35.7)
Severe dehydration[c]	913	152	16.7 (14.3, 19.2)	491	133	27.1 (23.2, 31.3)

Note CI, confidence interval; U_{sg}, urine specific gravity; WHO, World Health Organization.
[a]Excludes missing data.
[b]Malnutrition (stunting, undernutrition, and over-nutrition) is defined in Table 1.
[c]Dehydration as evidenced by highly concentrated urine, which we measured using urine test strips. Any dehydration ($U_{sg} \geq 1.020$), mild dehydration ($U_{sg} = 1.020$), moderate dehydration ($U_{sg} = 1.025$), and severe dehydration ($U_{sg} = 1.030$).
[d]Child < 13 years old.
[e]Teenager ≥ 13 years old.

3 PROTOCOL FOR A TRIAL ASSESSING THE IMPACTS OF SCHOOL-BASED WASH INTERVENTIONS ON CHILDREN'S HEALTH LITERACY, HAND-WASHING, AND NUTRITION STATUS IN LOW- AND MIDDLE-INCOME COUNTRIES

This chapter has been published as Sangalang et al. (2021) *International Journal of Environmental Research and Public Health 18*(1), 226;
https://doi.org/10.3390/ijerph18010226.

ABSTRACT

Diarrhoea, soil-transmitted helminth infection and malnutrition are leading causes of child mortality in low- and middle-income countries (LMICs). To reduce the prevalence of these diseases, effective interventions for adequate water, sanitation, and hygiene (WaSH) should be implemented. This paper describes the design of a cluster-randomized controlled trial that will compare the efficacy of four school-based WaSH interventions for improving children's health literacy, handwashing, and nutrition. Interventions consisted of (1) WaSH policy reinforcement; (2) low-, medium-, or high-volume health education; (3) hygiene supplies; and (4) WaSH facilities (e.g., toilets, urinals, handwashing basins) improvements. We randomly allocated school clusters from the intervention arm to one of four groups to compare with schools from the control arm. Primary outcomes were: children's health literacy, physical growth, nutrition status, and handwashing prevalence. Secondary outcomes were: children's self-reported health status and history of extreme hunger, satisfaction with WaSH facilities, and school restrooms' WaSH adequacy. We will measure differences in pre- and post-intervention outcomes and compare these differences between control and intervention arms. This research protocol can be a blueprint for future school-based WaSH intervention studies to be conducted in LMICs. Study protocols were approved by the ethics committees of the University of Bonn, Germany, and the University of the Philippines Manila. This trial was retroactively registered, ID number: DRKS00021623.

Keywords: children's health; health literacy; malnutrition; water; sanitation; and hygiene

3.1 INTRODUCTION

3.1.1 Background

Malnutrition, characterized by an imbalance in energy and/or nutrient intake [1], affects ~1 out of 3 people globally [2]. In 2017, 22.2% (150.8 million) of all children <5 years old were stunted [3]. In the same year, while 5.6% (38.3 million) children were overweight, 7.5% (50.5 million) were wasted [3], i.e., acutely undernourished or having low weight-for-height < –2 standard deviation (SD) of the World Health Organization (WHO) Child Growth Standards median [4]. Undernutrition, which is highly prevalent in low- and middle-income countries (LMICs), caused 45% (>29,000) of all deaths in children <5 [5,6]. Overweight and obesity caused ~7% (4 million) of all deaths and 120 million healthy years of life lost (disability-adjusted life years [DALYs]) [6]. Malnutrition, in all its forms, could cost society 5% (US $3.5 trillion) of the global gross domestic product (GDP) [7]. High economic losses disproportionately affect LMICs. Child undernutrition alone cost US $7 million and US $254 million in Swaziland and Uganda, respectively [8].

Preventing children's malnutrition involves preventing infectious diseases that precipitate imbalanced energy and/or nutrient intake. Diarrhea and soil-transmitted helminth (STH) infections, which affect millions of children in LMICs [9,10], can be prevented by interrupting routes of fecal-oral disease transmission through practicing proper hygiene, especially handwashing, handling food and disposing waste safely, and providing access to clean water for drinking and washing. Interventions for improving water, sanitation, and hygiene (WaSH) have been associated with decreased risk of diarrhea and STH infections, and consequently, decreased risk of malnutrition in various community settings [11,12]. For example, a cluster-randomized controlled trial (cluster-RCT) conducted in rural India found that the construction and promotion of latrines was associated with decreased diarrhea prevalence and increased weight-for-age z-score in children [11]. In Bangladesh, a cluster-RCT showed that an intervention incorporating water quality, sanitation, handwashing, and nutrition was associated with decreased diarrhea and increased height in children [12]. In 2016, 6000 deaths due to malnutrition could have been prevented by improving WaSH [13].

However, it is unclear how WaSH interventions in schools benefit children in LMICs, specifically in megacities, i.e., cities with >10 million inhabitants [14].

The Philippines, an archipelagic country in Southeast Asia, had a population of ~106.7 million in 2018 [15]. The Philippines' National Capital Region, known as Metro Manila, is identified as a megacity although it is not a single city but a metropolitan area comprising 16 cities. Metro Manila had ~12.9 million inhabitants in 2015 [16], representing 12.1% of the country's total population. In 2015 Metro Manila's population density was 20,785 persons per km^2 [17], or more than 4 times the population density of Beijing in 2014 [18]. Compared to other cities in LMICs, Metro Manila has a unique risk profile as a megacity that is exposed to ≥3 types of natural disasters [14], e.g., typhoons, floods, and volcanic eruptions. Thus, Metro Manila represents an important intersection of human health and the environment. Gaps in environmental health management have contributed to the increased prevalence of environment-related infectious diseases such as diarrhea and STH infections, making Metro Manila a precarious area to live in. This is an important issue because of long-term health consequences, e.g., growth stunting [10]. In 2018 more than half (53.9%) of households in the Philippines was food insecure [19]. In the Philippines the average daily intakes of whole grains and milk (45.5 g/day and 3.7 g/day, respectively) are lower compared to those in Indonesia (51 g/day and 7 g/day, respectively) [3]. Prevalence rates of school-age children's (6–10 years old) stunting, underweight, wasting/thinness, and overweight-for-height were: 24.5%, 25%, 7.6%, and 11.7%, respectively [20]. In the Asia region, the average stunting rate for children <5 years old is 21.8% but in the Philippines it is >30% [3]. The prevalence of low birth weight is higher in the Philippines (20%) compared to Ghana (14.2%) [3]. The prevalence of wasting for children <5 years old in the Philippines (5.6%) is higher than in Malawi (1.3%) [3]. While undernutrition alone is estimated to cost the Philippines USD $4.5 billion annually [21], the overall cost of hunger was USD $6.5 billion in 2013 [22].

The Philippines Department of Education (DepEd) oversees 54,602 public schools nationwide, hosting >22.6 million children during the School Year 2018–2019 [23]. While public schools receive government funding, they suffer from a lack of teachers and classrooms, and therefore, are overcrowded. The student-to-classroom ratio in Metro Manila public schools ranges from 50:1 to >100:1 [23,24]. This shortage of classrooms has caused the implementation of "double-shift" school-days, wherein one-half of students attend school during a morning shift (6:00 AM–12:00 PM) and another half attend school during an afternoon shift (12:00 PM–6:00 PM). The country's poorest children attend public schools. They are vulnerable to contracting diarrhea and STH infections because they are usually malnourished due to their low socioeconomic status (SES). The school environment, which they are regularly exposed to for prolonged periods, possibly plays a major role in this. Policies have been implemented to achieve adequate WaSH in schools (Supplementary materials, Box S3.1), yet there remain sizable gaps in WaSH management--gaps, which threaten the status of schools as health- and education-promoting environments and increase children's risk of disease.

3.1.2 Objectives

The WaSH in Manila Schools Trial aimed to identify an intervention that could better improve children's health. Our conceptual framework (Figure 3.1) depicts our pre-specified hypotheses (Figure 3.2). To test our hypotheses, we will compare a comprehensive school-based WaSH intervention with no intervention, rather the "standard of care". This comparison will enable us to estimate a potentially achievable reduction of inadequate WaSH, as well as estimate impacts on malnutrition reduction. Through our description of exposure-response relationships in Metro Manila schools, we will be able to provide estimates of the range of improvements that can be achieved in real-world, LMIC conditions where elements of adequate school WaSH, including improved sanitation, are typically combined with inadequate school WaSH and unimproved sanitation. Results of the trial will be reported in a forthcoming paper (unpublished; manuscript in preparation) [25]. In this paper, we present and discuss the rationale and design of a cluster-randomized controlled trial (RCT) that tested the efficacy of a school-based WaSH intervention. The research protocol we describe in this paper was designed and implemented in the Philippines but it can serve as a blueprint for conducting future intervention studies in other LMICs.

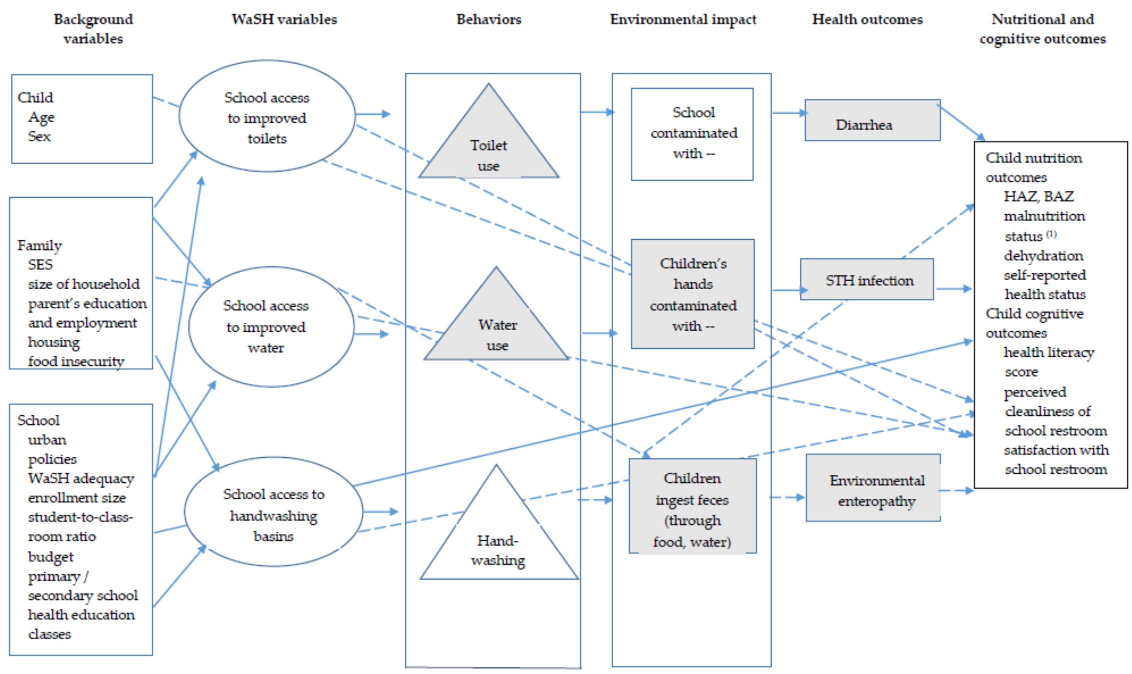


Figure 3.1 Conceptual framework for water, sanitation, and hygiene (WaSH) and child nutrition, hydration, and cognitive outcomes. Adapted from Dearden et al. [26]. Note: body mass index-for-age z-score (BAZ), height-for-age z-score (HAZ), socioeconomic status (SES); soil-transmitted helminth (STH), water, sanitation, and hygiene (WaSH). We will analyse relationships symbolized by solid arrows, not dashed arrows. Variables that may not be available for analysis during this phase of the research project are symbolized by grey colour. (1) Malnutrition status: stunted, undernourished, and over-nourished.

3.2 Research Methodology

3.2.1 Study Overview and Design

WaSH in Manila Schools was a research project aimed at improving children's environmental health by addressing inadequate school WaSH and promoting health literacy and hygiene practices (Figure 3.2). We implemented the project from January 2017 to February 2019, first conducting an observational study [27] to assess the WaSH situation in 15 public schools in Metro Manila, and then conducting a longitudinal study to develop, implement, and evaluate WaSH interventions in the same public schools (Figure 3.2). We conducted a cluster-RCT to address three specific aims (Figure 3.2) and compare the efficacy of four school-based WaSH intervention packages. Each intervention package consisted of different combinations of four elements: (1) WaSH policy reinforcement, (2) health education, (3) hygiene supplies, and (4) WaSH facilities (e.g., toilets, urinals, handwashing basins) improvements (Supplementary materials, Table S3.9).

I. Aims

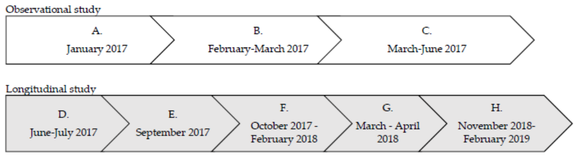
Overall project aims
1. To address knowledge gaps related to WaSH in schools, quantifying inadequacies and identifying areas for improvement;
2. To identify school-based WaSH interventions that are effective in improving children's health and nutrition outcomes and promoting hygiene behaviors, specifically handwashing;
3. To improve school WaSH environments and children's hygiene-related health literacy with the aim of decreasing risk of disease and malnutrition.

Observational study
Overall aim: #1, to address knowledge gaps related to WaSH in schools, quantifying inadequacies and identifying areas for improvement.
Specific aims:
1. To describe the WaSH situation in 15 public schools in Metro Manila.
2. To measure the prevalence of children's diarrhea, soil-transmitted helminth infection, and malnutrition (stunting, undernutrition, and overnutrition).
3. To identify individual- and school-level risk factors associated with children's diarrhea, soil-transmitted helminth infection, and malnutrition.

Longitudinal study: Intervention development, implementation, and evaluation.
Overall aims #2 and #3, to identify school-based WaSH interventions that are effective in improving children's health and nutrition outcomes and promoting hygiene behaviors, specifically handwashing; and to improve school WaSH environments and children's hygiene-related health literacy with the aim of decreasing risk of disease and malnutrition.
Specific aims:
1. To measure the effect of a randomized WaSH intervention on malnutrition and health literacy in a diverse population of public school students (age >= 9 years old), who were exposed to inadequate WaSH. We hypothesize that, compared to students from control schools, students from intervention schools would have greater improvements in physical growth (decreased stunting, undernutrition, overnutrition) and health literacy;
2. To assess the exposure-response associations between the education component of the WaSH intervention and health outcomes. Although we will obtain a measurement of the overall effect of the intervention from the 1st aim, it is important to analyze exposure-response to enable quantitative risk assessment and formulation of policy recommendations for improving WaSH in schools. We hypothesize that, compared to students from control schools, students from intervention schools who received high-volume health education would have greater physical growth and health literacy improvements;
3. To measure the extent to which health effects are associated with intervention status or exposure to inadequate WaSH. Research questions were: In intervention schools receiving WaSH supplies/equipment, does high-volume health education increase children's health literacy and prevalence of handwashing more than in schools with non-high-volume health education? Does high-volume health education, when combined with repair or installation of WaSH facilities (e.g. toilets, urinals, handwashing units), increase schools' WaSH adequacy more than schools with non-high-volume health education? We hypothesized that students from intervention schools who received high-volume health education, when compared with students from control schools, would have decreased exposure to inadequate WaSH, decreased prevalence of malnutrition, and increased health literacy.

(**a**)

II. Timeline



Phase	Activities
A	○ Began formative research (Figure S2)
B	○ Conducted cross-sectional school surveys (1)
C	○ Conducted cross-sectional household surveys (1)
D	○ Conducted pre-intervention assessments (school surveys); afterward, launched intervention with 1st health education session. • At same 15 schools (Phase B) but with different sample of children.
E	○ Developed and planned intervention package: • obtained permissions; • coordinated with school personnel about schedules; • procured materials and labor for intervention activities; • organized delivery of equipment and supplies to schools.
F	○ Launched full-scale intervention package comprised of: • 2nd-4th health education sessions; • hygiene promotion workshop for teachers; • soap-making workshop for parents; • school restroom cleaning contest; • poster contest; • songwriting workshop; • repair of WaSH facilities; • provision of hygiene equipment and supplies; • installation of WaSH hardware (toilets, urinals, and handwashing basins). ○ Intervention concluded with 4th health education session; began post-intervention assessments with same sample of children (Phase D).
G	○ Completed final post-intervention (2) assessment; conducted water quality testing. ○ Conducted final visits to schools to: • Disseminate summary of findings and recommendations; • Complete and transfer documentation of research activities for school records (research portfolio). ○ Attended end-of-year school activities: • Community Stakeholders' Recognition Day; • Graduation Ceremony and Recognition Dinner.
H	○ Conducted household questionnaire for children (3): • With same sample of children (Phase D and F), although some children had graduated or transferred to different schools that were not involved in our project.

(**b**)

Figure 3.2 WaSH in Manila Schools project aims and timeline. Note: water, sanitation, and hygiene (WaSH). (a) Aims of overall project, observational study, and longitudinal study. (b) Timelines for observational study and longitudinal study, including research activities. (1) Please see References [27]. (2) Eight months after implementing the intervention, we revisited children from the control and intervention arms for a follow-up assessment that used the same study design as the baseline assessment. We used the same survey instruments to measure: children's health literacy (Supplementary materials, Tables S3.3 and S3.4) and health and nutrition outcomes; children's handwashing prevalence; school restrooms' WaSH adequacy; and schools' WaSH policies. (3) In November 2018, 17 months after implementing the intervention, we administered a household questionnaire for children (Supplementary materials, Table S3.13), some of whom had graduated and/or transferred to different schools. We completed the household questionnaire in February 2019.

This was a two-arm cluster-RCT (Supplementary materials, Figure S3.3), with one intervention arm and one control arm. The control arm received no intervention, rather the "standard of care", which we defined as WaSH policy reinforcement, a hygiene workshop for teachers, and two health education sessions. The intervention arm was further divided into four groups (A, B, C, and D), based on the volume (low, medium, or high) of health education provided. Cluster units were public schools located in three cities of Metro Manila, Philippines, where many people, including a majority of public school children, were exposed to inadequate WaSH.

3.2.2 Study Population

For primary schools, we recruited students in grades 5 and 6 and for secondary schools in grades 7 and 10. These grade levels were chosen because we wanted to involve students who were: (1) developmentally mature enough to use and have perceptions about school WaSH facilities; (2) capable of responding independently or with minimal assistance to our questionnaire using a tablet or smartphone; and (3) able to actively participate in intervention activities (for inclusion and exclusion criteria for students, see Supplementary materials, Table S3.10).

3.2.3 Sampling and Recruitment

We conducted formative research (Supplementary materials, Figure S3.4) to prepare for the implementation of our intervention. We previously described how we estimated the sample size using the Lynch formula [27]. The target population was all the public school children in Metro Manila, where in School Year 2014–2015 a total of 2,059,447 public school children (1,373,852 elementary and 685,595 secondary school children) were enrolled [23]. We inflated the sample by 30% and 45% to account for nonresponse and refusal, respectively, and then inflated the sample by another 5% to account for differences in schools’ enrolment sizes. The target sample size was N = 760; we enrolled 756 students at baseline and 703 students at the 8-month follow-up (retention rate: 86%) (Figure 3.3).

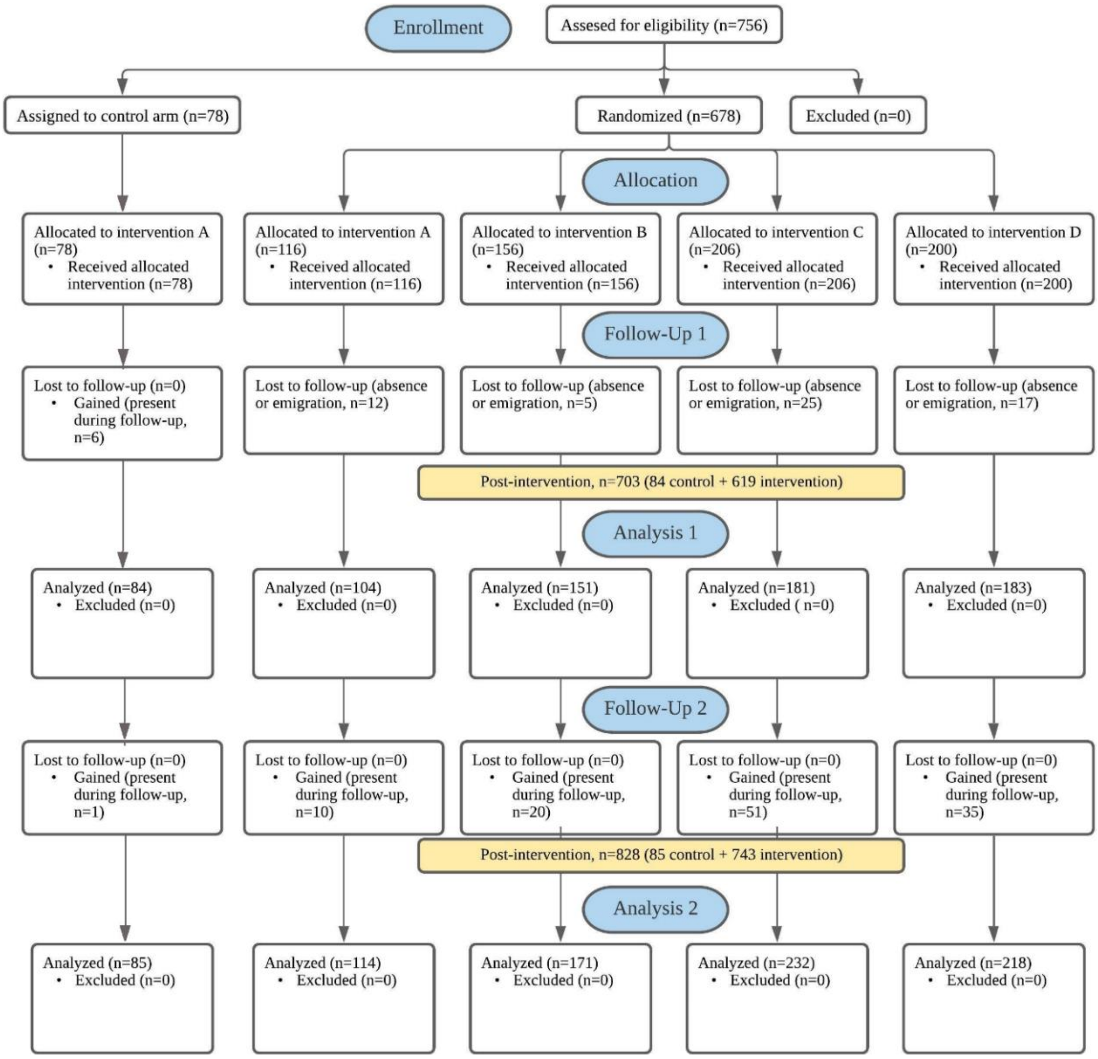


Figure 3.3 Assignment of participants and completed follow-up: flow diagram based on CONsolidated Standards of Reporting Trials (CONSORT) [28].

We selected schools located in Manila, Navotas, and Quezon City (Figure 3.4) because they were geographically and demographically representative of cities in Metro Manila. We recruited the school principals from the 15 public schools that participated in our previous observational study [27]. We used convenience, rather than probabilistic, sampling, choosing to revisit the same 15 schools because of existing relationships of trust and cooperation with school principals and personnel. These factors can facilitate communication and collaboration, which were crucial because we aimed to maintain a long-term working relationship with schools in spite of our limited resources in time, personnel, and materials. We previously described our multi-stage cluster sampling strategy [27]. Based on the school's enrollment size, 1–2 class sections were selected to obtain a target sample of ~50 students per school. We recruited entire class sections as a whole rather than groups of students from multiple class sections so as not to interrupt on-going classroom instruction with our research activities. We decided not to re-recruit the students from our previous observational study as a new school year had begun, resulting in students advancing up to the next grade level (e.g., from grade 5 to 6) and moving to different class sections, as well as some students transferring to different schools that were not involved in our study. No monetary reimbursement was offered to school principals, and all schools were compensated (Supplementary materials, Table S3.14) with printed research portfolios, certificates of appreciation, classroom viewings of an educational film promoting handwashing, and hand hygiene gel.

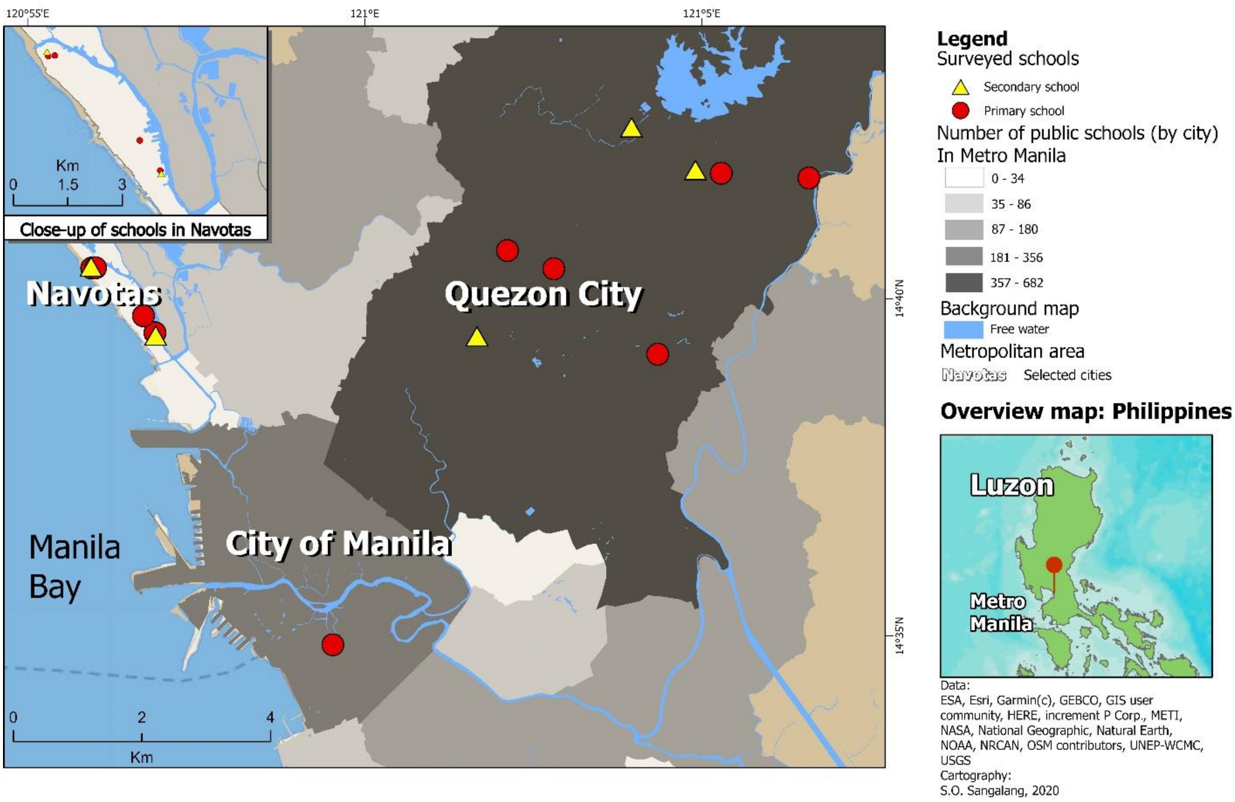


Figure 3.4 Map of study area with points marking the location of study schools. The map shows the study area in the National Capital Region, also known as Metro Manila, in northern Philippines, with study schools plotted as points. The red pushpin marker in the lower left inset map indicates where the location of the study area is within the Philippines, specifically in the northern most island group of Luzon.

3.2.4 Ethics Approval

The ethics committees of the University of Bonn, Germany (Number 216/16), and the University of the Philippines Manila (Number 2017–0113) provided written approvals for the study. Before conducting the school surveys we obtained written approval from the DepEd through division superintendents. Written informed consent was provided by school principals in loco parentis, i.e., in the place of a parent, for the children's participation. Prior to conducting our study, we described to the children the study procedures in an easy to understand way using the local language (Filipino/Tagalog). We emphasized that participation in our study was voluntary and that anyone could decide to stop participating in the study anytime. We encouraged children to ask the research team any questions they might have. We accepted children's affirmative agreement ("assent") to participate in the study as soon as they actively showed a willingness to join the research project by completing the questionnaire and undergoing a health examination. We retroactively registered our study in the German Clinical Trials Registry (DRKS), ID number: DRKS00021623. Study registration was delayed due to logistical and human resource constraints. We strictly followed the protocols, which were developed before data collection. This ensured that the study's quality was not impaired.

3.2.5 Data Collection

3.2.5.1. Assessing Primary Intervention Outcomes

First we assessed children's health literacy, measured by two continuous variables (hygiene literacy and handwashing literacy scores) via questionnaire (Supplementary materials, Tables S3.3 and S3.4). Second we assessed child growth, measured by continuous variables (z-scores for height-for-age [HAZ] and body mass index-for-age [BAZ]) and binary variables (prevalence of malnutrition [stunting, undernutrition, and overnutrition]), via anthropometry (Table 3.1). HAZ is a linear growth indicator that indicates if the child has the appropriate stature for his/her age, while BAZ is an indicator of growth that indicates if the child has the appropriate ratio of weight and height for his/her age, according to WHO guidelines [4,29–32]. We used the WHO AnthroPlus (for children 5–19 years old) software (version 3.2.2., WHO, Geneva, Switzerland) to obtain HAZ and BAZ for each child. Third we assessed handwashing prevalence via observation according to standard operating procedure (SOPs) (Figure S3.5).

Table 3.1 Operational definitions.

Indicator		**Definition**	**Reference**
Malnutrition			
Stunting	Stunted	HAZ < −2	[4,31,32]
Undernutrition	Underweight ("thin")	−3 < BAZ < −2	[4,29,30]
	Wasted ("severely thin")	BAZ < −3	[4,29,30]
Over-nutrition	Overweight	1 < BAZ < 2	[4,29,30]
	Obese	BAZ > 2	[4,29,30]
Acute dehydration			[33]
Concentrated urine		sg ≥ 1.020	Category
Moderately concentrated urine		sg = 1.025	used in present study
Severely concentrated urine		sg = 1.030	Category
WaSH adequacy			used in present study
Sanitation			
Improved	Facility that hygienically separates human excreta from human contact	e.g. flush toilet, pour-flush latrines, ventilated improved pit latrines and pit latrines with a slab or covered pit	[34]
Unimproved	Facility that does not hygienically separates human excreta from human contact	e.g. pit latrines without slabs or platforms or open pit, hanging latrines, bucket latrines, open defecation, disposal of human feces with other forms of solid waste	[34]
Male student-to-toilet ratio	Less than 50 students	1 toilet, 1 urinal, 1 handwashing basin	[35]
	50 or more students	2 toilets, 1 urinal, 2 handwashing basins	[35]
	For each additional 100 students	1 toilet, 1 urinal, 1 handwashing basin	[35]
Female student-to-toilet ratio	Less than 30 students	1 toilet, 1 handwashing basin	[35]
	30 - 100 students	2 toilets, 2 handwashing basins	[35]
	For each additional 50 students	1 toilet	[35]
	For each additional 100 students	1 handwashing basin	[35]
Male student-to-toilet ratio	50 students	1 toilet, 1 urinal (or 50 cm of urinal wall)	[36]
Female student-to-toilet ratio	25 students	1 toilet	[36]
Student-to-HW basin ratio	N/A	N/A	No WHO guidelines available
Male student-to-toilet ratio	Low	≤ 50:1	Category used in present study
	Medium	51:1–100:1	Category used in present study
	High	≥ 101:1	Category used in present study
Female student-to-toilet ratio	Low	≤ 50:1	Category used in present study

	Medium	51:1–100:1	Category used in present study
	High	≥ 101:1	Category used in present study
Student-to-HW basin ratio	Low	≤ 50:1	Category used in present study
	Medium	51:1-150:1	Category used in present study
	High	≥151:1	Category used in present study

Note: body mass index (BMI); body mass index-for-age Z-score (BAZ); Department of Health Philippines (DOH); height-for-age Z-score (HAZ); not applicable (N/A); urine specific gravity = U_{sg}; water, sanitation, and hygiene (WaSH); weight-for-age Z-score (WAZ); World Health Organization (WHO).BAZ is BMI, which is calculated by weight (kg) / [height (m)]^2. We measured BAZ instead of WAZ because the latter is appropriate only for children < 5. We used BAZ and HAZ measurements, along with children's age, to calculate anthropometric indices, which were computed as Z-scores (the number of standard deviations [SDs] in relation to the mean of the standard population). When computing Z-scores, we referred to the 2007 WHO database for child growth standards [4,29–32]. We used the WHO AnthroPlus (for children 5-19 years old) software (version 3.2.2., WHO, Geneva, Switzerland) to obtain HAZ and BAZ for each child. We defined acute dehydration as having highly concentrated urine defined as urine sg ≥ 1.020 [33]. We measured urine sg via point-of-care urinalysis using urine test strips as described in Figure S3. We measured urine sg as a continuous variable and as a binary variable: concentrated urine, sg ≥ 1.020 (yes/no), moderately concentrated urine, sg = 1.025, and highly concentrated urine, sg = 1.030). Urine sg estimates the ratio of solutes (e.g. electrolytes, nitrogenous chemicals) compared with distilled water, which has a sg of 1.000. The normal range of urine sg is 1.003–1.030, with higher numbers indicating a greater concentration of solutes and, consequently, decreased hydration (known as "dehydration") [33]. The gold standard for measuring urine sg is urine osmolality, although this test is invasive, expensive, and not practical in field settings. We defined children as dehydrated if urine sg ≥ 1.020. This cutoff corresponds to a urine osmolality of > 800 mOsm/kg H_2O, which is the cutoff used in previous studies involving dehydrated children [37,38].

3.2.5.2 Assessing Secondary Intervention Outcomes

First we assessed children's overall health status, extreme hunger prevalence, and satisfaction with and perceived cleanliness of schools' WaSH facilities, measured by binary variables, via questionnaire (Supplementary materials, Table S3.11 and S3.12). We assessed acute dehydration, measured by incidence of highly concentrated urine (U_{sg} ≥ 1.020) [33,37,38] (Table 3.1), via urinalysis using urine test strips (Insight Urinalysis Reagent Strips, Acon Laboratories Inc., San Diego, CA, USA). Urine test strips are an affordable, easy to use, and reliable way to perform urinalysis in field settings [39]. Second we assessed school principals' satisfaction with schools' WaSH facilities and children's hygiene practices, measured by binary variables, via interview. Third we assessed, via observation, schools' WaSH adequacy, measured by continuous and binary variables describing availability, accessibility, cleanliness, and functionality, according to guidelines from the Philippines DepED and Department of Health (DOH) [35,40]. We previously reported the data collection tools we used for conducting health examinations, interviews with school principals, and school restroom inspections [27]. Data collection tools were pilot-tested and improved prior to beginning this trial.

During our previous observational study, we found that children were avoiding or not using school restrooms, possibly due to a perceived lack of cleanliness or lack of privacy. Findings indicated that avoidance and non-use of school restrooms increased children's risk of diarrhea. Thus, we aimed to see if our intervention was effective in improving children's perceptions about school restrooms, with the hope that children would use school restrooms rather than avoid using them. Also, we found that school WaSH policies were in place, yet school principals reported being unsatisfied with WaSH facilities and children's hygiene behaviors. School principals' perceptions about WaSH could affect efforts to implement, maintain, and sustain improvements, all of which influence children's health and hygiene behaviors. Thus, we aimed to see if our intervention was effective in improving school principals' perceptions about school WaSH facilities.

3.2.5.3 Baseline Survey and Randomization

At baseline, we conducted a four-part school-based survey (Supplementary materials, Figure S3.5) to measure: (1) children's health literacy and nutrition status; (2) handwashing prevalence; (3) school restrooms' WaSH adequacy; and (4) schools' WaSH policies. We developed a self-administered health literacy questionnaire for children in English and then translated it to Tagalog (Filipino language) (Supplementary materials, Tables S3.11 and S3.12). We made one version for primary and one version for secondary school children. The QuickTapSurvey© app (Formstack LLC, Fishers, IN, USA), installed on password-protected tablets and smartphones, was used to administer all survey instruments. It is a cloud-based data collection tool that allows for simultaneous offline data entry and stamping with global positioning system (GPS) coordinates, date, and time. We applied validation rules and range limits for precise data entry.

The research supervisor conducted a full-day (eight hours) initial training workshop (Supplementary materials, Table S3.15) for research assistants before conducting school surveys. Each school survey was conducted by a team of 5–7 rotating research assistants, directly managed by the research supervisor. To begin the school survey, we first explained the study's aims, objectives, and methods to the children in Tagalog (Supplementary materials, Figure S3.5). We emphasized that participation in our study was voluntary and anonymous, and that results would remain confidential and have no impact on anyone's school grades. Children's full name, date of birth, and telephone number were collected and stored in a separate Microsoft© Excel spreadsheet secured in password-protected tablets. Next, we assigned children unique identification (ID) numbers and gave them each three tickets that were printed with their ID number. The ticketing system was a quality control measure that ensured that all children provided all the requested data. Children were instructed to give one ticket to the assigned research assistant at every station that they visited during the school survey (Supplementary materials, Figure S3.5).

After obtaining data from the children, research assistants completed the school restroom inspection checklist, took photos of WaSH facilities, and interviewed school principals or representatives, inputting all data into the app. We obtained school administrative data, e.g., budget for maintenance and other operating expenses, from the DepEd. At the end of each workday, research assistants discussed their work with each other, shared lessons learned, and identified areas for improvement. Upon accessing an internet hotspot, we used the app to transmit anonymized data to a central database via cloud storage. Research assistants periodically checked uploaded data to verify the completeness of data upload and identify discrepant, missing, or duplicate data. When needed, appropriate remedial action was taken, e.g., re-training research assistants or clarifying instructions for children.

After completing baseline surveys, we assigned two schools to the control arm and 13 schools to the intervention arm (Figure 3.3). We purposefully assigned two schools to the control arm because one school had a school principal who directly asked us to participate in our previous observational study. The other school was integrated (offering all possible grade levels, from kindergarten to grade 12) and was the location where we had pilot-tested our survey instruments before the observational study. We randomly allocated schools in the intervention arm to one of four groups. One research assistant and the research supervisor conducted randomization in Microsoft© Excel as follows: (1) In one column, we listed the names of the 13 schools in the intervention arm, with one row representing one school. (2) In another column, we listed the four intervention groups (A, B, C, and D), with one row representing one group. We previously determined how many schools would be allocated to each group (Supplementary materials, Table S3.9). (3) In a third column, we used Excel's random number function and ranked the schools, assigning each school to either group A, B, C, or D (Supplementary materials, Table S3.9). Except for the research supervisor, all research assistants, study participants (children), school personnel, and parents were blinded to the assignment of schools to the intervention arm and subsequent random allocation to intervention groups A–D.

3.2.5.4 Follow-Up and Other Assessments

Eight months later, we conducted a follow-up assessment by implementing the same methodology (i.e., 4-part school-based survey) that we used at baseline (Supplementary materials, Figure S3.5) and measuring the same types of outcomes (e.g., children's health literacy and nutrition status, handwashing prevalence, school restrooms' WaSH adequacy, and schools' WaSH policies). Nine months later (17 months after the first health education session), we conducted a household questionnaire for children (Supplementary materials, Table S3.13). Thus, we were able to assess risk factors at the individual-, school-, and home-levels (Table 3.2).

We expected the intervention to influence children's knowledge, behavior, and health outcomes. We defined indicators of the intervention's impact as changes in children's primary and secondary outcomes. We measured the difference between outcomes from the eight-month follow-up and baseline. We compared differences between control and intervention arms. We collected samples for water quality testing from study schools and a separate sample of households (located in the school neighborhood) after post-intervention assessments, as previously reported [27].

Table 3.2 Data collection during the WaSH in Manila Schools project.

Instrument	Types of Data Collected	Frequency and Time Period (s)
WaSH-related knowledge, attitudes, and practices (KAP) questionnaire for children	Self-reported: ● Demographics ● Perceptions about and use of school WaSH facilities ● Hygiene behavior (e.g., handwashing) ● Health history ● Food security	1 time: February–March 2017
Health examination (form) for children	Observed: ● Height ● Weight ● Urine specific gravity	3 times: February–March 2017; different sample of students during June–July 2017 and February–March 2018
Interview (form) for school principal [(1)]	Self-reported: ● Perceptions about school WaSH facilities and students' hygiene ● WaSH-related policies	2 times: March–June 2017; November–December 2018
School restroom inspection checklist	Observed: ● Availability, quantity, and quality of school WaSH facilities	2 times: February–March 2017; September–December 2018
Interview (form) for parent/guardian	Self-reported: ● Demographics ● Food security ● Hygiene behavior (e.g., handwashing)	1 time: March–June 2017
Home restroom inspection checklist	Observed: ● Availability and quality of home WaSH facilities	1 time: March–June 2017
Health literacy questionnaire for children	Self-reported: ● Demographics ● Understanding of hygiene concepts and handwashing	2 times: June–July 2017 and February–March 2018
Handwashing observation form	Observed: ● Children's handwashing behavior	2 times: October 2017; February–March 2018
Water quality testing form	Observed: ● Indicators of water quality	1 time: April 2018 [(2)]
Household questionnaire for children	Self-reported: ● Demographics ● Perceptions about school and home WaSH facilities ● Hygiene behavior (e.g., handwashing) ● Health and nutrition status ● Food security ● Exposure to second-hand smoke	1 time: November 2018–February 2019

N/A	● Home and household characteristics ● Parent/guardian's education and employment ● Secondary school administration data (3)	Various

Note: Department of Education Philippines (DepEd); Philippines Department of Health (DOH); knowledge, attitudes, and practices (KAP); maintenance and other operating expenses (MOOE); water, sanitation, and hygiene (WaSH); World Health Organization (WHO).We assessed risk factors for desired outcomes at the individual-, school-, and home-levels. At the individual-level, we assessed demographics, self-reported health status, history of extreme hunger (e.g., feeling too hungry to fall asleep), exposure to second-hand smoke at home, and perceptions of school WaSH facilities. At the school-level, we measured the adequacy of WaSH facilities by counting the number and assessing the quality (e.g., cleanliness, functionality) of toilets, urinals, and handwashing units. We estimated student-to-toilet and student-to-handwashing unit ratios based on the DOH guidelines (Table 3.1). We decided not to base our estimations on the WHO guidelines (Table 3.1) because public schools in many parts of the Philippines, similar to other LMICs, currently have limited capacity to effectively address the over-crowding of students on school campus. We asked school principals about WaSH-related school policies, e.g., "Is there a school policy to clean the students' restrooms daily?" [27]. We retrieved secondary school administrative data from school secretaries and the DepEd. At the household-level, we assessed the family's demographics (e.g., the number of adults and children in the home), food insecurity, experience of having to ask/beg for food; parent's employment status, education, literacy, history of physical or intellectual disability; access to and adequacy of the home's WaSH facilities. To assess the family's socioeconomic status we examined ownership of household appliances and electronic devices (e.g., refrigerator, mobile phone), ownership of transportation vehicles, most frequently used mode of transportation to school, material of the home's flooring, and availability of electricity. Eight months after implementing the intervention, we revisited children from the control and intervention arms for a follow-up assessment that used the same study design as the baseline assessment. We used the same survey instruments that we used in the previous observational study [4] to measure: children's health literacy and nutrition outcomes, handwashing prevalence, school restrooms' WaSH adequacy, and schools' WaSH policies. Seventeen months after implementing the intervention, we administered a household questionnaire for children, some of whom had graduated and/or transferred to different schools since participating in the previous follow-up assessment. (1) Some school principals had left their respective schools by the time we conducted our follow-up interviews. Thus, the pre- and post-intervention samples of school principals were not comprised of the exact same individuals for all schools. (2) In our analyses, we included secondary water quality testing data that was collected in 2016 for one school from the control arm. (3) School administration data: e.g., enrolment, number of classrooms, and MOOE budget.

3.2.6 Intervention

The four parts of the intervention were: (1) WaSH policy reinforcement, (2) health education, (3) hygiene supplies, and (4) WaSH facilities improvements (Supplementary materials, Table S3.9). We implemented the intervention over eight months, from June 2017 to February 2018 (Figure 3.2). The development of the intervention was informed by findings from our previous observational study and baseline survey, as well as inputs from research assistants with expertise in the local context and stakeholders, e.g., school principals, teachers, and janitors. We also conducted opinion polls with students. It was important for us to use participatory research methods that engaged stakeholders so that we could assess whether our intervention would be acceptable or sustainable after the research project ended.

School principals were presented with a research portfolio containing recommendations for enforcing existing WaSH policies (Supplementary materials, Figure S3.1). We conducted one-hour hygiene promotion workshops for teachers, explaining the importance of improving WaSH in schools to achieve the United Nations' (UN) Sustainable Development Goal (SDG) 6 [41], related to WaSH, and complying with the DepEd's Order No. 10 [40], related to WaSH in schools. The workshop was valuable for teachers because it helped them gain new ideas about how to present to children specific health education topics, and see how big of a role classroom activities play in achieving schools' WaSH policy goals.

At the core of our intervention was health education. Research assistants conducted interactive verbal presentations for children, who, depending on which intervention group they belonged to, received two to four health education sessions that lasted one hour each. The content of the health education sessions (Supplementary materials, Figure S3.7) was based on the existing DepEd curriculum and open educational resources from, e.g., the United States Centers for Disease Control and Prevention (CDC) and Environmental Protection Agency (EPA). Microsoft© PowerPoint slides, with visually appealing graphics to attract children's attention, were created (Supplementary materials, Figure S3.7). Each health education session included a brief lecture, class discussion, and a trivia game. We also incorporated role-playing, other games, and singing the "Happy Birthday" song to teach children the correct duration of time for handwashing. Besides health education sessions, we used mixed methods to pique children's interest, invite active participation, and encourage a sense of empowerment about hygiene at the personal- and environment-levels. For example, we implemented poster-making and school restroom-cleaning contests, as well as songwriting workshops specifically for children and adolescents from secondary schools. Research assistants also developed an original educational video, filmed in Tagalog, called "Hygiene Heroes", to promote proper handwashing (Supplementary materials, Figure [Film], S3.8). After launching the intervention, we promoted adherence with various communication strategies (Supplementary materials, Table S3.16).

3.2.7 Trial and Data Management

Our trial involved a non-invasive, non-pharmacological intervention that posed little risk to participants. Thus, we saw no need for trial steering or data monitoring committees, nor did we see a need for interim data analysis. The research supervisor, who was based at the University of the Philippines Diliman for the entire duration of the trial, led the day-to-day management of data. The research team conducted the trial according to protocol, as approved by ethics committees, to ensure the safety of study participants, maintain the trust of stakeholders, preserve data quality, and maintain the integrity of the project.

Research assistants collected data using password-protected tablets and smartphones offline. We uploaded the data daily to the secure QuickTapSurvey© server, and then refreshed tablets and smartphones, deleting all data from the devices. We downloaded data from the QuickTapSurvey server as Microsoft© Excel files, which eliminated the need for manual data entry and its associated risks for error. We manually inspected data for discrepancies and inconsistencies and addressed these according to the SOPs (Supplementary materials, Figure S3.5). We used key matching data (children's date of birth and telephone number) to link data from children's questionnaires with data from health examinations.

3.2.7.1. Protocol Standardization and Data Quality Control

To ensure the standardization of research activities within and between cities, across all data collection periods, as well as within and between various teams of research assistants, we used SOPs and a detailed school visit itinerary (Supplementary materials, Figure

S3.5). The research supervisor explained and demonstrated the SOPs and itinerary in English and Tagalog during an in-person training workshop with research assistants before conducting field research. The research supervisor verified research assistants' comprehension by return-demonstration. The research supervisor directly oversaw data collection and provided onsite, real-time feedback, providing additional training as needed. Data quality was monitored regularly, and discrepancies were immediately discussed and resolved within the research team. Research assistants were encouraged to propose solutions and workflow improvements.

3.2.8 Dissemination

We discussed preliminary results with project partners and provided research portfolios (Supplementary materials, Figure S3.6), containing a summary of results, policy recommendations, and outline for an action plan, to school principals for dissemination to schoolteachers, parents, and children. The research portfolio was valuable for school principals because it helped them to describe their school's progress toward WaSH-related goals, set by the DepEd. In the Philippines, we presented our methods and summary of interventions to a non-government organization and an international organization. We presented preliminary results at international conferences. Full results will be reported in a forthcoming paper [25].

3.2.9 Statistical Analysis

Because our study contains multiple arms (1 control and 4 intervention arms), it is necessary to develop a strategy for conducting statistical analysis that takes into account the study's 5 arms, parallel design, and unequal allocation ratio between control and intervention arms. We will use an adjustment method to control for type I error due to the study's multiple-arm design. Because we simultaneously assessed multiple outcomes, we will need to adjust for a possible multiple comparisons effect. One possible adjustment method is the Benjamini–Hochberg procedure [42], which controls for the false discovery rate (10%). We used unequal allocation, making the intervention group larger than the control group, because we aimed to increase the precision of the intervention comparison. Also, we aimed to make the study more acceptable to study participants and researchers by decreasing the likelihood of being allocated to the control group and not receiving the intervention. Because we aim to know whether and how interventions differ, we will not use a single global test of significance, which would compare all groups simultaneously. Rather we will use a dose-response model to examine trends. We will conduct all analyses by using the originally assigned intervention status (i.e., intention to treat), comparing each intervention arm against the control arm.

We will examine the role of missing data in the interpretation of findings. If we find no statistically significant difference between children who were missing data and children who were not missing data for key outcomes, then we will conclude that data were missing at random (MAR), though not missing completely at random (MCAR). MAR means that all data, within groups defined by the observed data, had an equal chance of being missing, and that the reason why data were missing is due to a known characteristic of the data themselves [43]. In our study, the possible reasons for MAR will likely be: nonresponse (some children did not answer all of the questions in the questionnaire) or loss to follow-up due to school absence or discontinued school enrollment because of drop-out, graduation, or relocation. On the other hand, MCAR will less likely be found in our study because it means that all data had an equal chance of being missing and that the reason why data were missing is not due to the data themselves [43]. In field research, this may be an unrealistic occurrence. We will consider using multiple imputation (MI) or full information maximum likelihood (FIML) to handle MAR data. An advantage of FIML is that it uses all available data provided by a given study participant. We will use Stata, version 15 (StataCorp, College Station, TX, USA), for all data analyses.

3.2.9.1 Descriptive Analyses

We will conduct descriptive analyses, pre- and post-intervention, to measure study participation, demographic characteristics, and outcomes of interest. We will report baseline characteristics for all five study arms. For each primary and secondary outcome, we will report results (e.g., means, proportions) for each arm, including the estimated effect size and precision. To describe exposure to inadequate WaSH at school and at home, we will measure frequencies and interquartile ranges (IQRs) relevant to schools' and homes' WaSH facilities. Data from school inspections will be summarized at the school-level by measuring the mean scores of individual facility inspections. To describe outcomes of poor health literacy, poor handwashing, and malnutrition, we will measure prevalence rates using contingency tables with estimates of standard error (SE) and precision.

3.2.9.2 Inferential Statistical Analyses

To address study aims 1 and 3 (Figure 3.2), we will compare the study arms, using two-sided tests for primary outcomes. For continuous variables, we will use the t-test to calculate the mean weight differences between the control and intervention arms. For binary variables, we will use Poisson regression to compare the control and intervention arms according to their relative risk (RR). We will use multiple logistic regression models to analyse exposure-response: $g = (E[Ai]) = \beta 0 + \beta 1Bi + \gamma Ci$, where Ai is the primary outcome of interest, g( ) is the appropriate link function (identity for height and weight, logistic for stunting and poor health literacy), Bi is the continuous exposure of interest, and Ci is the vector of confounders. We describe proposed models in Supplementary materials, Figure S3.2, and will describe full models in a forthcoming paper [25].

To assess risk factors of health, health literacy, and handwashing outcomes, we will use multiple logistic regression models that account for school-level clustering, estimate precision with 95% confidence intervals (CI), and *p*-values, and produce adjusted odds ratios (aORs). Clustering by school takes into account potential intragroup correlation among children from the same school and enables us to adjust the SE of estimates. aORs control for possible confounders (e.g., children's age and sex, parent's educational background and employment status, presence of toilet and handwashing basin inside home, household food insecurity). We will use confounders to calculate an adjusted effect estimate to account for baseline differences between the control and intervention arms. We will use three multiple logistic regression models (Box S2): (1) model A for poor hygiene literacy only, poor handwashing literacy only, and both poor hygiene literacy and poor handwashing literacy; (2) model B for malnutrition, i.e., stunting only, undernutrition only, and overnutrition only; and

(3) model C for poor health status only, extreme hunger only, and both poor health status and extreme hunger.

We will use generalized linear mixed models (GLMMs), which are appropriate for longitudinal data, to determine if the intervention was effective in improving our outcomes of interest. GLMMs are useful for measuring intervention impacts in complex datasets, i.e., when different types of variables (e.g., binary, continuous) are assessed at different time periods, particularly when assessments are made at the group- rather than individual-level. We will use GLMMs to estimate the effect of each intervention compared to the control group. To measure the intervention's impact, we will estimate differences between pre- and post-intervention outcomes.

3.3 Discussion

Inadequate-WaSH-related diseases, specifically malnutrition, diarrhoea, and STH infection, continue to be leading causes of child mortality and morbidity, particularly in LMICs [5,10,13]. One reason may be that many knowledge gaps still exist and hinder progress on school WaSH. For example, evidence about the relationship between health literacy and handwashing has been limited to adults [44] and older adolescents (age 16–19 years old) [45]. Little is known about how school WaSH impacts child growth and what kind of framework is needed to guide the development of child malnutrition prevention programs. Evidence is limited on which combinations of WaSH interventions could be implemented to achieve optimal health for urban poor children.

We have performed one of the most comprehensive assessments of school WaSH, children's WaSH-related knowledge, attitudes, and practices (KAP), malnutrition, and risk factors at the individual-, school-, and home-levels. We will fill data gaps on school WaSH facilities, quantifying available resources and deficiencies and identifying areas for improvement. Data from our monitoring of school WaSH facilities will further the understanding contributed by previous studies that were limited by cross-sectional study designs [46,47]. To our knowledge, our study was the first school-based WaSH intervention trial to be conducted in multiple cities of Metro Manila using a common protocol, which will enable the comparability, transferability, and generalizability of the findings to similar LMIC settings. We will be among the first to report the impacts of school WaSH on malnutrition in an under-assessed population of children and younger adolescents (13–15 years old) from a tropical megacity in a LMIC. Our study will show how children's physical growth could be improved by school-based WaSH interventions, providing key information for malnutrition prevention programs. This is crucial for populations in LMICs, where the prevalence of non-communicable diseases (NCDs), such as malnutrition, is rising rapidly and steeply [2]. By including indicators of malnutrition, food and water insecurity, and policy effectiveness, our study will highlight the need for a new framework to assess the long-term health impacts of inadequate school WaSH. By identifying risk factors of poor health literacy, our study will also address an urgent need to create evidence-based strategies aimed at promoting behavior change, i.e., hygiene practices, that can last beyond childhood and endure along the life course into adulthood.

Our study included intervention components (e.g., health education, poster-making and restroom cleaning contests, promotion of hygiene practices through behavioral reinforcement) that are likely to be operationalized at scale in similar high-risk, low-resource settings in LMICs because they were feasible, acceptable, and affordable. Our study will support using best practices in public health promotion and enhancing local research capacity. We provided local researchers with training about: community health, population-based research, and participatory research methods; assessments of child growth and cognitive development; use of noninvasive markers to evaluate hydration status.

The interpretation of our study findings will likely be limited because of bias due to the non-random recruitment of schools and non-random sampling of children, and the lack of randomization when we assigned school clusters to control or intervention arms. We used outcome measures that could increase the risk of bias by misclassifying children or not controlling for confounding. We used self-reported outcome measures to assess food insecurity and socioeconomic status. We used urine test strips to assess dehydration. However, we did not corroborate or triangulate findings with other sources of data. It is also possible that our assessment of health literacy via questionnaire would introduce bias. We will need to account for many missing responses due to children dropping out of our study because they graduated and/or transferred to a different school. We collected data on many outcomes and will likely run the risk of seeing a "multiple comparisons effect". This may occur because as the number of outcome measurements increases, so does the tendency of seeing a false-positive [48].

3.3.1 Implications for Research and Policy

More studies are needed to improve health literacy assessment, expanding its scope to include more relevant content. It would be helpful to corroborate observed handwashing with children's self-reported handwashing, not just after using the toilet but also before eating. Another option would be to measure a handwashing-proxy, e.g., monitoring the usage of water, soap, and paper/towels in schools as an indicator of children's handwashing. Enhanced measurement of dehydration ought to be explored by using a refractometer instead of urine test strips, and then corroborating findings with observed clinical signs of dehydration and children's subjective report of thirst. Sound study designs are needed to improve the generalizability of findings and reduce the risk of bias. It would be helpful to randomly recruit schools and children and randomly assign school clusters to control and intervention arms. It would be useful to design a cohort study that would follow children into adulthood to gain a better understanding of the long-term effects of inadequate WaSH on human growth and nutrition status. Studies are needed to describe the relationship between schools' menstruation management services and children's health and education outcomes.

Our findings will demonstrate the need for improved development and enforcement of school WaSH policies, as well as health education and hygiene practices. When synthesized with data from formative research on the barriers and facilitators of handwashing and the use of school WaSH facilities, our findings will enable health practitioners, educators, and other researchers to better promote adherence to proper handwashing. Specifically, our work can inform efforts to improve hygiene education and prevent the neglect of school WaSH facilities by promoting proper operation, maintenance, cleaning, and adequate financing. Our study is very timely and relevant, offering evidence to decision-makers who are responsible for managing the safe reopening and operation of schools during the Corona disease 2019 (COVID-19) pandemic. Our results will provide support for maintaining school WaSH facilities, including water security, and above all, promoting handwashing. Threats to children's health in relation to school WaSH have recently been exacerbated by the COVID-19 pandemic, especially in resource-constrained settings like public schools in LMICs. Urgent, evidence-based action is required to protect vulnerable populations of children in these settings where citizens face a disproportionately high risk for COVID-19-related death and disease, in addition to severe economic, environmental, and sociopolitical consequences [49,50]. The research protocol described in this paper can serve as a blueprint for future intervention studies to be conducted in other LMICs.

3.4 Conclusions

Effective school-based WaSH interventions are needed to better protect children's health, especially in LMICs. The design of this cluster-RCT aims to measure the effectiveness of a comprehensive school-based WaSH intervention by measuring impacts on children's health literacy, handwashing, and nutrition and comparing impacts across study arms that received different volumes (low, medium, or high) of health education. This will enable a deeper understanding about how school WaSH can be better managed to promote children's health and prevent disease, particularly in precarious environments constrained by limited resources such as urban poor megacities in LMICs.

Author Contributions

Conceptualization, S.O.S., C.B., and T.K.; methodology, S.O.S., C.B., and T.K.; software, validation, formal analysis, writing—original draft preparation, S.O.S.; investigation, S.O.S., S.A.J.M., Z.J.O., A.L.G.L., D.T., J.C.V., P.A.A.S., M.O., N.O.P., R.M.Z.O., M.V.J.C.A.; data curation, S.O.S., S.A.J.M., Z.J.O., A.L.G.L., D.T., P.A.A.S., and M.V.; implementation of intervention: S.O.S., S.A.J.M., Z.J.O., A.L.G.L., D.T., J.C.V., M.O., N.O.P., R.J.F.C., A.J.T.B., S.M.F.M., J.G.G., C.P.A., and E.C.L.; writing—review and editing, all authors; visualization, S.O.S., S.A.J.M., and Z.J.O.; supervision, C.B., T.K.; project administration, S.O.S.; funding acquisition, C.B. and S.O.S. All authors have read and agreed to the published version of the manuscript.

Funding

This research incorporated a PhD thesis, taking place at the Center for Development Research (ZEF), University of Bonn, Germany. It was funded by S.O.S.'s PhD research grants received from: the ZEF, University of Bonn; the Fiat Panis Foundation; and the Katholische Akademische Auslaenderdienst (KAAD).

Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committees of the University of Bonn, Germany (Number 216/16) (28 September 2016), and the University of the Philippines Manila (Number 2017–0113) (23 February 2017).

Informed Consent Statement

Before conducting the school surveys we obtained written approval from the Philippines Department of Education through division superintendents. Written informed consent was provided, as per the local practice, by school principals in loco parentis, i.e., in the place of a parent, for the children's participation. Prior to conducting our study, we described to the children the study procedures in an easy to understand way using the local language (Filipino/Tagalog). We emphasized that participation in our study was voluntary and that anyone could decide to stop participating in the study anytime. We encouraged children to ask the research team any questions they might have. We accepted children's affirmative agreement ("assent") to participate in the study as soon as they actively showed a willingness to join the research project by completing the questionnaire and undergoing a health examination.

Data Availability Statement

Not applicable.

Acknowledgments

We gratefully acknowledge all members of the WaSH in Manila Schools project team, study participants and their parents/guardians, school superintendents, school principals, teachers, secretaries, maintenance, security, front gate, and canteen personnel. For institutional support, the authors thank: Guenther Manske, Maike Retat-Amin, Max Voigt, Anne Grimminger, and Anna Yuen from the Doctoral Program of the ZEF, University of Bonn; Sabine Aengenendt-Baer from the ZEFc Secretariat; Alma van der Veen from the ZEF Public Relations Department; Lemnuel V. Aragones, Melanie Bantongbakal, Raian Lapresca, Mark Edward Jolejole, Paul Ezekiel Iosaria, Faye Denna, and Mikhael Cosep from the Institute of Environmental Science and Meteorology (IESM), University of the Philippines Diliman. We thank Kyoung-Woong Kim and Young-Gwang Kim from the Gwangju Institute of Science and Technology (GIST). We thank the Manila Water Company Inc. for providing technical guidance regarding water sampling. We thank Mr. Christoph Hoeser from the Institute for Hygiene and Public Health (IHPH), University of Bonn, for providing technical Geographic Information System (GIS) support and helpful advice about cartography. We thank Andrey Egorov from the United States Environmental Protection Agency (EPA) for his technical guidance regarding school-based WaSH surveys. We thank our team of field research assistants for their invaluable contributions: Jessie Bunao, Claire Olaivar, Paula Miclat, Genes Maylem, Erina Molia, Erika Macapagal, Guadalupe Diaz, Anton Valdellon, Patrick Tuano, Christian Ebonite, Cheyenne Sastrillas, Aira Galaroza, Mark Ramos, Malou Cumagon, and Janine Liao.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. WHO. Malnutrition. Key Facts. Available online: https://www.who.int/news-room/fact-sheets/detail/malnutrition#:~:text=Malnutrition (accessed on 30 October 2020).

2. WHO. *The Double Burden of Malnutrition Policy Brief*; World Health Organization: Geneva, Switzerland, 2017.
3. Development Initiatives. *2018 Global Nutrition Report: Shining a Light to Spur Action on Nutrition*; Development Initiatives: Bristol, UK, 2018.
4. WHO. *Nutrition Landscape Information System (NLIS) Country Profile Indicators Interpretation Guide*; World Health Organization: Geneva, Switzerland, 2010.
5. Black, R.E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; de Onis, M.; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.; et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013, *382*, 427–451, doi:10.1016/S0140-6736(13)60937-X.
6. Naghavi, M.; Abajobir, A.A.; Abbafati, C.; Abbas, K.M.; Abd-Allah, F.; Abera, S.F.; Aboyans, V.; Adetokunboh, O.; Afshin, A.; Agrawal, A.; et al. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017, *390*, 1151–1210, doi:10.1016/S0140-6736(17)32152-9.
7. FAO. *Food Systems for Better Nutrition*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2013.
8. AUC; NEPAD; UNECA; WFP. *The Cost of Hunger in Africa: Social and Economic Impact of Child Undernutrition in Egypt, Ethiopia, Swaziland and Uganda Abridged Report*; United Nations Economic Commission for Africa: Addis Ababa, Ethiopia, 2014.
9. Troeger, C.; Blacker, B.F.; Khalil, I.A.; Rao, P.C.; Cao, S.; Zimsen, S.R.; Albertson, S.B.; Stanaway, J.D.; Deshpande, A.; Abebe, Z.; et al. Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhea in 195 countries: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet Infect. Dis.* 2018, *18*, 1211–1228, doi:10.1016/S1473-3099(18)30362-1.
10. Weatherhead, J.E.; Hotez, P.J.; Mejia, R. The global state of helminth control and elimination in children. *Pediatr. Clin. North Am.* 2017, *64*, 867–877, doi:10.1016/j.pcl.2017.03.005.
11. Clasen, T.; Boisson, S.; Routray, P.; Torondel, B.; Bell, M.; Cumming, O.; Ensink, J.; Freeman, M.; Jenkins, M.; Odagiri, M.; et al. Effectiveness of a rural sanitation programme

on diarrhea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: A cluster-randomised trial. *Lancet Glob. Health* 2014, *2*, e645–e653, doi:10.1016/S2214-109X(14)70307-9.

12. Luby, S.P.; Rahman, M.; Arnold, B.F.; Unicomb, L.; Ashraf, S.; Winch, P.J.; Stewart, C.P.; Begum, F.; Hussain, F.; Benjamin-Chung, J.; et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhea and child growth in rural Bangladesh: A cluster randomised controlled trial. *Lancet Glob. Health 2018*, *6*, e302–e315, doi:10.1016/S2214-109X(17)30490-4.
13. Prüss-Ustün, A.; Wolf, J.; Bartram, J.; Clasen, T.; Cumming, O.; Freeman, M.C.; Gordon, B.; Hunter, P.R.; Medlicott, K.; Johnston, R. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An updated analysis with a focus on low-and middle-income countries. *Int. J. Hyg. Environ. Health* 2019, *222*, 765–777, doi:10.1016/j.ijheh.2019.05.004.
14. UN. *The World's Cities in 2018: Data Booklet*; United Nations: New York, NY, USA, 2018.
15. World Bank. Available online: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=PH (accessed on 24 September 2020).
16. Philippine Statistics Authority. Available online: https://psa.gov.ph/content/population-national-capital-region-based-2015-census-population-0 (accessed on 1 September 2020).
17. Philippine Statistics Authority. Available online: https://psa.gov.ph/content/philippine-population-density-based-2015-census-population (accessed on 2 September 2020).
18. Our World in Data. UN Habitat GUO. Available online: https://ourworldindata.org/grapher/population-density-by-city?country=Bangkok~Beijing~Delhi~Dhaka~Manila~Mexico%20City~Mumbai~Sao%20Paulo~Shanghai~Taipei~ Tokyo (accessed on 2 September 2020).
19. Malabad, C.G. Food security status of Filipino households. In Proceedings of the 2019 National Nutrition Summit, Manila, Philippines, 25 June 2019.
20. Vargas, M.B. Nutritional status of Filipino school children (6–10 years old). In Proceedings of the 2019 National Nutrition Summit, Manila, Philippines, 25 June 2019.

21. UNICEF. *The Economic Consequences of Undernutrition in the Philippines: A Damage Assessment Report (DAR)*; United Nations International Children's Emergency Fund: Mandaluyong, Philippines, 2018.
22. Save the Children. *Cost of Hunger: Philippines. The Economic Impact of Child Undernutrition on Education and Productivity in the Philippines*; Save the Children Philippines: Makati City, Philippines, 2016.
23. DepEd. Elementary and junior and senior high school enrollment, school years 2014–2019. Unpublished work; dataset.
24. DepEd. Number of public classrooms in elementary and junior high school, enrollment for school years 2018–2019. Unpublished work; dataset.
25. Sangalang, S.; Ottong, Z.J.; Medina, S.A.M.; Lemence, A.L.G.; Singson, P.A.; Anglo, M.V.; Valencia, J.C.; Canja, R.J.; Kistemann, T.; Borgemeister, C.; et al. Effectiveness of a School-Based Water, Sanitation, and Hygiene Intervention to Improve Handwashing, Health Literacy, and Nutrition Status: Results from a Cluster-Randomized Controlled Trial. Unpublished work, manuscript in preparation.
26. Dearden, K., Schott, W., Crookston, B., Humphries, D., Penny, M., Behrman J.R. Children with access to improved sanitation but not improved water are at lower risk of stunting compared to children without access: A cohort study in Ethiopia, India, Peru, and Vietnam. *BMC Public Health* 2017, *17*, doi:10.1186/s12889-017-40331.
27. Sangalang, S.; Prado, N.; Lemence, A.; Cayetano, M.; Lu, J.; Valencia, J.; Kistemann, T.; Borgemeister, C. Diarrhea, Helminth Infection, Dehydration, and Malnutrition Associated with Water, Sanitation, and Hygiene Facilities and Poor Handwashing in Schools in Metro Manila, Philippines: A Cross-Sectional Study. *Am. J. Trop. Med. Hyg.* doi:10.1101/2020.12.13.20248141. Under review.
28. Schulz, K.F.; Altman, D.G.; Moher, D.; CONSORT Group. CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. *BMJ* 2010, *23*, 332–340, doi:10.1136/bmj.c332.
29. WHO. BMI-for-Age Boys. 5 to 19 years (z-scores) 2007. Available online: https://www.who.int/growthref/bmifa_boys_z_5_19_labels.pdf?ua=1 (accessed on 4 September 2020).

30. WHO. BMI-for-Age Girls. 5 to 19 years (z-scores) 2007. Available online: https://www.who.int/growthref/bmifa_girls_z_5_19_labels.pdf?ua=1 (accessed on 4 September 2020).
31. WHO. Height-for-Age Boys. 5 to 19 years (z-scores) 2007. Available online: https://www.who.int/growthref/cht_hfa_boys_z_5_19years.pdf?ua=1 (accessed on 4 September 2020).
32. WHO. Height-for-Age Girls. 5 to 19 years (z-scores) 2007. Available online: https://www.who.int/growthref/cht_hfa_girls_z_5_19years.pdf?ua=1 (accessed on 4 September 2020).
33. Pagana, K.D.; Pagana, T.J.; Pagana, T.N. *Mosby's Diagnostic and Laboratory Test Reference*, 12th ed.; Elsevier Inc.: Saint Louis, MO, USA, 2015; pp. 671–672, 956–957.
34. WHO; UNICEF. *Progress on Sanitation and Drinking-Water: 2010 Update*; World Health Organization: Geneva, Switzerland, 2010.
35. DOH. *Implementing Rules and Regulations of Chapter VI, "School Sanitation and Health Services", of the Code on Sanitation of the Philippines (P.D. 856)*; Department of Health: Manila, Philippines, 1998.
36. WHO. *Water, Sanitation and Hygiene Standards for Schools in Low-Cost Settings*; Adams, J., Bartram J., Chartier, Y., Sims, J., Eds.; World Health Organization: Geneva, Switzerland, 2009.
37. Bar-David, Y.; Urkin, J.; Kozminsky, E. The effect of voluntary dehydration on cognitive functions of elementary school children. *Acta Paediatr.* 2005, *94*, 1667–1673, doi:10.1080/08035250500254670.
38. Bar-David, Y.; Urkin, J.; Landau, D.; Bar-David, Z.; Pilpel, D. Voluntary dehydration among elementary school children residing in a hot arid environment. *J. Hum. Nutr. Diet* 2009, *22*, 455–460, doi:10.1111/j.1365-277X.2009.00960.x.
39. Baron, S.; Courbebaisse, M.; Lepicard, E.M.; Friedlander, G. Assessment of hydration status in a large population. *Br. J. Nutr.* 2015, *113*, 147–158, doi:10.1017/S0007114514003213.

40. DepEd. DepEd Order No. 10, s. 26. *Policy and Guidelines for the Comprehensive Water, Sanitation, and Hygiene in Schools (WinS) Program*; Department of Education: Pasig City, Philippines, 2016.
41. UN. *Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development*; United Nations: Geneva, Switzerland, 2016.
42. Benjamini, Y.; Hochberg, Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. *J. R. Stat. Soc. Ser. B* 1995, *57*, 289–300.
43. Little, R.J.A.; Rubin, D.B. *Statistical Analysis with Missing Data*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2020.
44. Or, P.P.L.; Wong, B.Y.M.; Chung, J.W.Y. To investigate the association between the health literacy and hand hygiene practices of the older adults to help them fight against infectious diseases in Hong Kong. *Am. J. Infect. Control* 2020, *48*, 485–489, doi:10.1016/j.ajic.2019.12.021.
45. Riiser, K.; Helseth, S.; Haraldstad, K.; Torbjørnsen, A.; Richardsen, K. Adolescents' health literacy, health protective measures, and health-related quality of life during the Covid-19 pandemic. *PLoS ONE* 2020, *15*, e0238161, doi:10.1371/journal.pone.0238161.
46. Appiah-Brempong, E.; Harris, M.J.; Newton, S.; Gulis, G. Examining school-based hygiene facilities: A quantitative assessment in a Ghanaian municipality. *BMC Public Health* 2018, *18*, 581, doi:10.1186/s12889-018-5491-9.
47. Jordanova, T.; Cronk, R.; Obando, W.; Medina, O.Z.; Kinoshita, R.; Bartram, J. Water, sanitation, and hygiene in schools in low socio-economic regions in Nicaragua: A cross-sectional survey. *Int. J. Environ. Res. Public Health* 2015, *12*, 6197–6217, doi:10.3390/ijerph120606197.
48. Lindquist, M.A.; Mejia, A. Zen and the art of multiple comparisons. *Psychosom. Med.* 2015, *77*, 114–125, doi:10.1097/PSY.0000000000000148.
49. Valensisi, G. COVID-19 and Global Poverty: Are LDCs Being Left Behind?. *Eur. J. Dev. Res.* 2020, *32*, 1535–1557. https://doi.org/10.1057/s41287-020-00314-8.

50. Lapidor, E. Out of the spotlight: COVID-19 and the Global South. Available online: https://www.justsecurity.org/71570/out-of-the-spotlight-covid-19-and-the-global-south/ (accessed on 28 August 2020).

3.A Supplementary materials

https://www.mdpi.com/1660-4601/18/1/226/s1

Contents

Figure S3.1 Policies relevant to WaSH in schools.

SDG 6 [1]	**DepEd Order Number 10 (2016) [2]**
Ensure access to water and sanitation for all. Targets: 6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all. 6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. 6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.	Policy and Guidelines for the Comprehensive Water, Sanitation and Hygiene in Schools (WinS) Program. Targets: 1. Water: All schools shall have an organized system to make adequate and safe drinking water as well as clean water for handwashing, toilet use, menstrual hygiene management, and cleaning purposes available to all students during school hours; 2. Sanitation: All schools shall have adequate, clean, functional, safe, and accessible toilet facilities that meet the pupil-to-bowl ratio as stipulated in the Philippine Sanitation Code; maintain cleanliness and safety in and the immediate vicinity of school premises through school-based solid waste management, proper drainage, and the elimination of all possible breeding grounds for mosquitoes to prevent vector-borne diseases; and ensure safety in food handling and preparation; 3. Hygiene: All students in school shall perform supervised daily group handwashing with soap and tooth brushing with fluoride, while a system and support mechanisms for effective menstrual hygiene management shall be ensured in all schools; 4. Health Education: All teachers, heads of schools, facilities coordinators, and health personnel shall be oriented on the DepEd WinS program. Trained teachers can conduct Health Education in coordination with community leaders during Parent-Teacher Association (PTA) meetings. All pupils/students shall have a higher

	awareness of correct hygiene and sanitation practices and develop positive health behaviors; 5. Deworming: At least 85 percent of all students shall be dewormed semi-annually; 6. Capacity Building: All DepEd WinS program implementers shall undergo orientation on the program as needed.
Other SDGS[2]	
2. Zero Hunger. 2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round. 2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons. 3. Ensure healthy lives and promote well-being for all at all ages. 3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.	3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being. 3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. 4. Quality Education. 4.A Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, nonviolent, inclusive and effective learning environments for all

Note: acquired immunodeficiency syndrome (AIDS); Department of Education Philippines = DepEd; parent-teacher association (PTA); Sustainable Development Goal (SDG); United Nations (UN); water, sanitation, and hygiene (WaSH); water, sanitation and hygiene in schools (WinS).
[1] Please see References for Supplementary materials, 1.
[2] Please see References for Supplementary materials, 2.

Figure S3.2 Equation and proposed variables to be included in planned logistic regression models.

I. Equation

We will analyze the sample to identify and assess associations between outcomes and exposures (i.e. risk factors). We will use three logistic regression models: model A for poor hygiene literacy only, poor handwashing literacy only, and both poor hygiene and handwashing literacy; model B for malnutrition, i.e. stunting only, underweight only, and over-nutrition only; model C for poor health status only, extreme hunger only, and both poor health status and extreme hunger. We list our models' factors (variables) below. To measure associations between outcomes and exposures, we will use the following equation as the basis of our logistic regression models:

$$\log it(\pi_{abcdefg}) = \beta_1 San_b \times \beta_2 San_c + Xc_{abc} + \Delta s_b + Ks_d + F_f + H_g + \zeta_m$$

where

π_{abcde} = dichotomous outcome for child *a* in school *b* in cluster *c* in survey *d* in matched group *e* from family *f* in home *g*

San_b = whether school has any sanitation

San_c = level of sanitation in school

C_{abc} = vector of child characteristics

S_b = vector of school characteristics

S_d = vector of survey characteristics

F_f = vector of family characteristics

H_g = vector of home characteristics

ζ_m = random intercept for matched group *m* that is assumed to be normally distributed with a mean of 0

II. Proposed variables

Model	Outcomes	Exposures
A	Poor hygiene literacy only, poor handwashing literacy only, and both poor hygiene literacy and poor	Female, early-teenager [1], stunted only, over-nutrition only, is not satisfied with school restroom, school-level prevalence rates of: does not wash hands at school, avoids school restroom, does not use school restroom, lacks privacy, insufficient number of restrooms in school, long lines in school restroom, lack of hygiene lessons in school, number of school restrooms, number of school toilets, number of school handwashing basins, school restroom lacks water, is not clean, lack of policy to clean school restroom daily, maximum MOOE budget

	handwashing literacy	[2], no toilet at home, no running water at home, no electricity at home, family has no cellphone, second-hand smoke in home, parent cannot read
B	Stunting only, undernutrition only, and over-nutrition only	Female, pre-teenager [3], poor hygiene literacy, poor handwashing literacy, is not satisfied with school restroom, number of school toilets, number of school handwashing basins, school restroom lacks water, is not clean, lack of policy to clean school restroom daily, maximum MOOE budget [2], annual school enrollment < 2,000 students, no toilet at home, no running water at home, no electricity at home, family has no cellphone, second-hand smoke in home, parent cannot read, insufficient food at home, lack of food variety, family cannot afford food, family asks other people for money to buy food, family eats pre-cooked food or fast food more often than freshly cooked food
C	Poor health status only, extreme hunger only, both poor health status and extreme hunger	Female, pre-teenager [3], stunted only, poor hygiene literacy, poor handwashing literacy, is not satisfied with school restroom, number of school toilets, number of school handwashing basins, school restroom lacks water, is not clean, lack of policy to clean school restroom daily, maximum MOOE budget [2], annual school enrollment < 2,000 students, no toilet at home, no running water at home, no electricity at home, family has no cellphone, family has no watch or clock, second-hand smoke in home, parent cannot read, insufficient food at home, lack of food variety, family cannot afford food, family asks other people for money to buy food, family eats pre-cooked food or fast food more often than freshly cooked food

Note: maintenance and other operating expenses (MOOE); United States Dollar (USD).
[1] Early-teenager: 13 - 14 years old.
[2] Maximum MOOE budget in USD.
[3] Pre-teenager: < 13 years old.

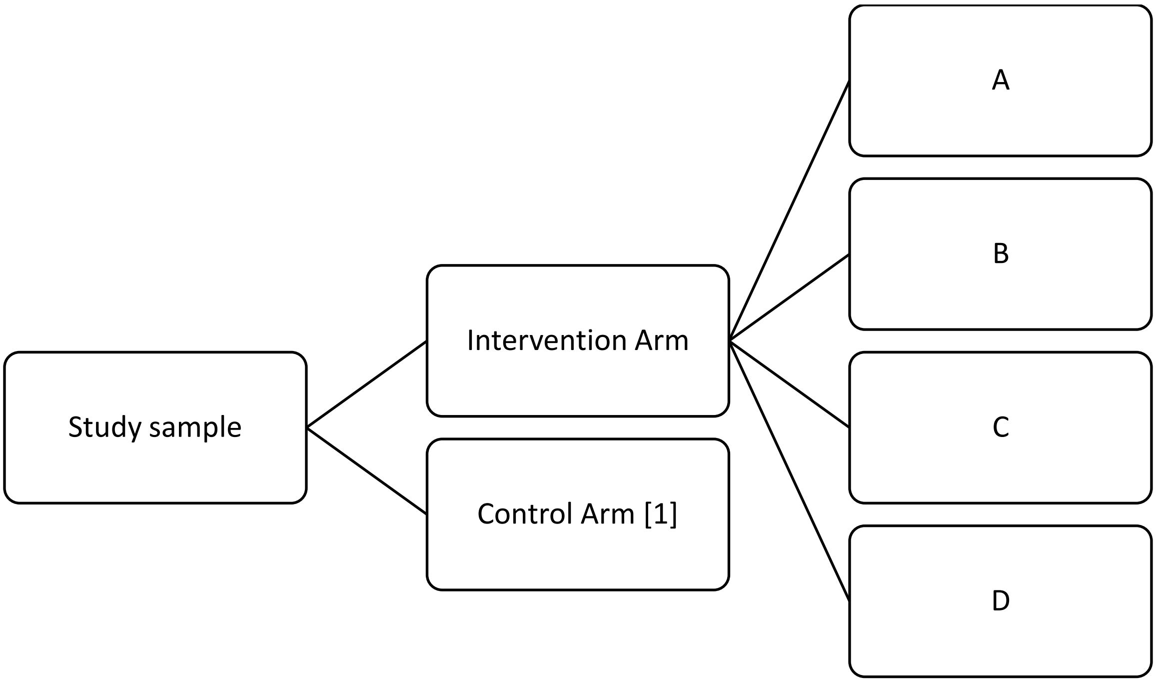


Figure S3.3 Diagram of control arm and intervention arm.

Intervention group	Intervention components received [2]
A	Policy recommendations, low-volume [3] health education, hygiene promotion workshop for teachers, poster contest, water purifier/dispenser for drinking water, and installation of toilets.
B	Policy recommendations, medium-volume [3] health education, hygiene promotion workshop for teachers, school restroom cleaning contest, hygiene supplies, and door locks for toilet cubicles.
C	Policy recommendations, high-volume [3] health education, hygiene promotion workshop for teachers, soap-making workshop, hygiene supplies, and repair of WaSH facilities.
D	Policy recommendations, medium-volume [3] health education, hygiene promotion workshop for teachers, poster contest, cleaning supplies for school janitors, and installation/construction of handwashing basins.

Note: water, sanitation, and hygiene (WaSH).
The intervention arm was divided into four groups based on the number of health education sessions (2-4) offered to study participants. Children did not know the schedule of intervention implementation in advance. It was not possible to completely blind them to the intervention as they directly received health education sessions and participated in classroom activities (e.g. contests). Many children were able to see the installation or repair of WaSH facilities, as these activities occurred on school grounds and sometimes during school-day hours. However, children were blinded to the provision of WaSH or hygiene

supplies (e.g. liquid hand soap), which we gave directly to school principals or representatives without any children present.

[1] Control arm: received no intervention, rather the standard of care, which we defined as WaSH policy recommendations, hygiene promotion workshop for teachers, and two health education sessions for children.

[2] We provide a detailed description of intervention components in Supplementary materials, Table S3.1.

[3] Low-, medium-, and high-volume health education referred to children receiving 2, 3, and 4 one-hour sessions, respectively.

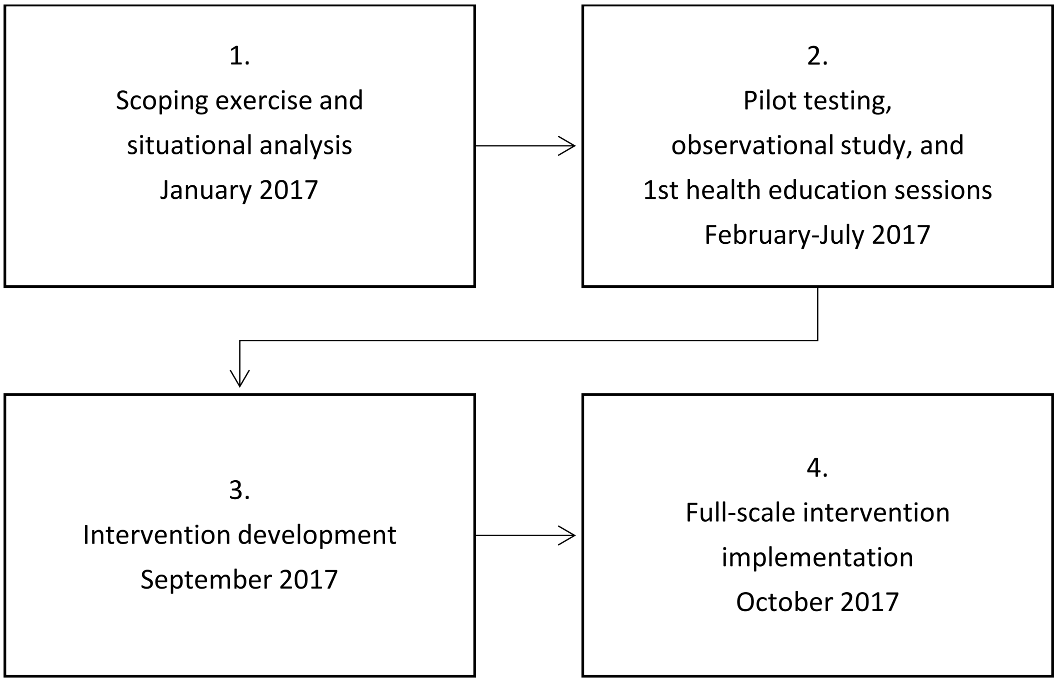
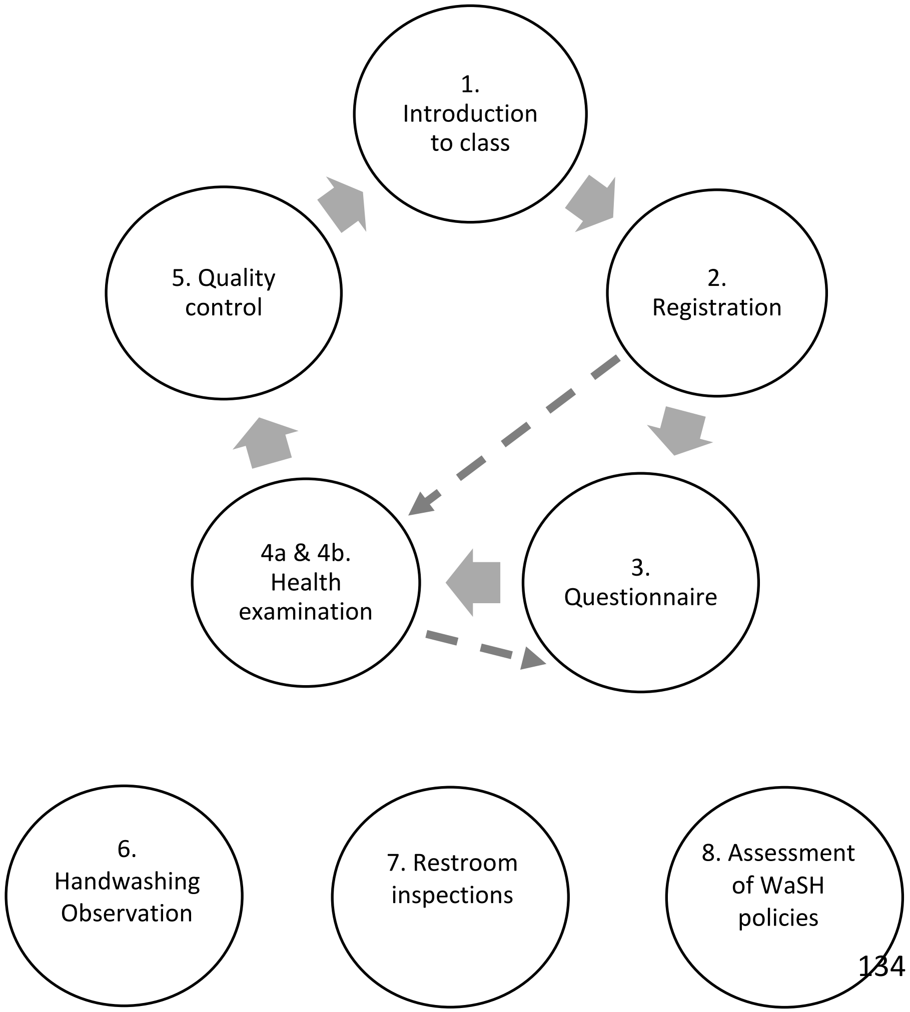


Figure S3.4 Formative research conducted to plan and develop intervention.
Note: water, sanitation, and hygiene (WaSH). We conducted formative research to plan our strategy of developing, implementing, and evaluating a comprehensive school-based WaSH intervention package. We carried out formative research as follows: 1) Scoping exercise to identify potential study schools; conduct of situational analysis to describe gaps in school WaSH management and assess learning needs of children. 2) Pilot testing of survey instruments; conduct of observational study [1] to describe WaSH situation in 15 public schools and assess health, nutrition, and hygiene practices of children. Conducted 1st health education sessions in June-July 2017. (In one school from the control arm, we conducted the 1st health education session in October 2017 to accommodate the class's schedule). 3) Process of intervention development that was informed by findings from our observational study, inputs from local research assistants, and feedback from stakeholders. Engagement with the offices of city mayors, engineers, public health, and captains of "barangays" (Tagalog for "smallest units of local government").The latter were responsible for the day-to-day activities within neighbourhoods wherein our study schools were located and where study participants lived. 4) Launch of full-scale intervention package in schools, which involved procurement and provision of WaSH equipment, supplies, and materials for facilities, e.g. toilets, urinals, and handwashing basins. [1] Please see References for Supplementary materials, 3.

Figure S3.5 Standard operating procedure (SOP) for pre- and post-intervention assessments, referred to as school surveys: contents, protocol, and workflow.



We conducted pre- and post-intervention assessments, referred to as school surveys, in June-July 2017 and February-March 2018. (We conducted the pre-intervention assessment at one school [from the control arm] in October 2017 to accommodate the class' schedule.) We assessed the same sample of children at baseline and at the 8-month follow-up.

Step	Station	Activities
1	Introduction	Upon arriving in the classroom, research assistants introduced themselves to the teacher and children. Research assistants explained, in Tagalog, the study's purpose, objectives, and methods. They explained that participation in the study was voluntary, anonymous, and confidential. They explained that data would not impact the children's school grades.

Step	Station	Activities
2	Registration	Research assistants asked children, one at a time, for his or her student identification (ID) number, date of birth, and telephone number. Then each child was assigned a unique study ID number. Data were inputted into a Master List (Excel file) stored on password-protected tablets or smartphones. Each child was given a set of 3 tickets containing his or her study ID number and instructed to wait for his or her turn to complete the health literacy questionnaire on an available tablet or smartphone. Due to the limited number of tablets and smartphones available, we dedicated at least one tablet to the height and weight station and one tablet to the urine station. All remaining tablets and smartphones were dedicated to the health literacy questionnaire station.
3	Questionnaire	Research assistants selected a group of 5-7 children, saying aloud the appropriate ID numbers, to begin the health literacy questionnaire. Children completed the health literacy questionnaire using an app installed on tablets and smartphones. Children answered the questionnaire independently and privately, away from the view of their classmates. Research assistants verified the completion of each child's questionnaire and collected from him or her the appropriately labelled ticket. Then the research assistant directed the child to proceed to the health examination station.
4	Health examination: height and weight	Research assistants measured children's standing height (to the nearest cm), without shoes, using a tape measure attached to the wall of the school building. We measured children's weight (to the nearest 0.1 kg), without shoes or any items inside their pockets, using a digital weighing scale (EKS Asia Ltd., Hong Kong, Special Administrative Region of the People's Republic of China). Research assistants inputted all data into the app.
	Health examination: urine	Research assistants gave children a plastic cup with their student ID number written on the outside of the cup. Research assistants asked children to take their

		cup to the restroom and fill the cup with their urine. Then research assistants received urine specimens and performed point-of-care urinalysis per protocol. According to the manufacturer's instructions, we dipped for at least 5-6 seconds one urine test strip (Insight Urinalysis Reagent Strips, Acon Laboratories Inc., San Diego, California, U.S.A.) into one urine specimen. After waiting at least 2-3 minutes, we interpreted the urinalysis results by comparing the color changes displayed on the urine test strip to the manufacturer-provided urinalysis interpretation guide. Urinalysis test results were interpreted by one research assistant and inputted into the app by another research assistant. We disposed of urine specimens, cups, and urine test strips according to protocol, immediately after completing our survey. Alternatively, at the beginning of the school survey, research assistants would call a group of 5-7 students to participate in the health examination before completing the health literacy questionnaire. Afterward, the students would be directed to complete the health literacy questionnaire.
5	Quality control	As a quality control measure, at the end of the school survey, but prior to leaving the school campus, we counted the number of responses saved in the tablets and smartphones. We verified that this number matched the total number of tickets collected from all stations (questionnaire, height and weight, and urine stations). This helped us to identify missing data if a child did not provide all the required data. If needed, then we would approach the child and ask him or her to provide the missing data.
6	Handwashing observation	We conducted unannounced handwashing observations directly after a school survey or on days where no school survey was conducted. We observed children who may or may not have participated in our school survey as described above (steps 1-4). To conduct the handwashing observations, we positioned ourselves inside or at the doorway of school restrooms to visualize whether children washed their hands after using the toilet or urinal, and if they used the correct

		handwashing technique and for the correct duration of time (≤ 20 seconds). We calculated school-level handwashing prevalence rates by taking the mean score of all observations performed at the same school.
7	Restroom inspections	We conducted visual inspections of schools' WaSH facilities, e.g. restrooms, handwashing areas. We assessed the facilities' adequacy according to national guidelines and recommendations by the WHO. We documented the facilities' adequacy using a standardized checklist that had been incorporated into the same survey app that was used for the students' data.
8	Assessment of WaSH policies	We interviewed school principals or their designated representatives to assess WaSH policies. We used a standardized interview script that had been incorporated into the same survey app that was used for the students' data.

Note: less than or equal to (≤); centimetre (cm); identification (ID); kilogram (kg); limited company (Ltd.); United States of America (U.S.A.); World Health Organization (WHO). Steps 6-8 were not always done on the same day as the students' health examination and questionnaire. The four parts of the school survey, which used the same methodology during pre- and post-intervention, are marked in blue colour.

Figure S3.6 Research portfolio give to school principals: contents and examples of documentation.

Research Portfolio for [redacted]

Project Name	Impact of inadequate water, sanitation, and hygiene, and food insecurity on children in public schools in Metro Manila.
Research Institutions	Institute of Environmental Science and Meteorology, University of the Philippines, Diliman; Center for Development Research, University of Bonn, Germany.
Research Dates	February 2017 – April 2018

Contents of Research Portfolio

I. Acknowledgements
II. Project partners
III. Summary
IV. Timeline
V. Research questions
VI. Research objectives
VII. Research methods
VIII. Research findings
IX. Recommendations/action plan
X. Appendix
 i. Memos
 ii. Photos
 iii. Data summaries

Data collection

Electronic tablets loaded with an app were used to collect data from:
a. questionnaires and interviews from stakeholders (principals, students)
b. students' health exams (height, weight, urinalysis)
c. inspections of school and home restrooms.
d. The water quality testing will be conducted on April 2018.

Research Findings

Summary of Main Findings

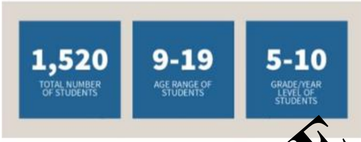
Availability
- Lack of basic resources
- No running water, soap, tissue paper, or towels

Access
- Lack of wheelchair ramps

Quality
- Many equipment/facilities are not fully operational or well maintained

Quantity
- Too many students, too few toilets/urinals

Study Population



In the first phase of the study, there was a total number of 1, 520 respondents with the age range of 9 – 19 and with the grade level of 5 – 10.

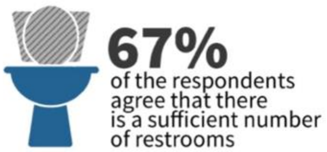
Among these respondents, **93%** uses the school restrooms, **84%** do not avoid using the restrooms but **only 48% are satisfied** with the schools' restrooms.

Adequacy of WASH in school

The availability of the following in comfort rooms.

The quality of the comfort room:

The accessibility of the comfort room:



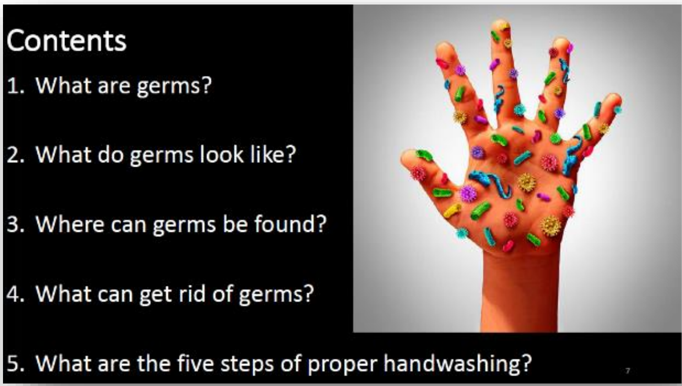
Key Findings for T[redacted]
(More data to follow)

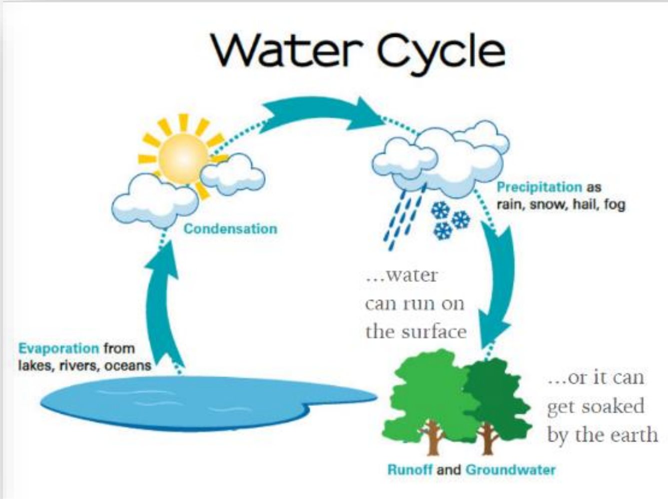
Total Enrollment (6): **1989**
Males: **1057**
Females: **932**
Grade/No. of students in Phase 1: **5/90**
No. of students' households: **5**
Grade/No. of students in Phase 2: **6/82**
Grade/No. of students in Phase 3: (to follow).

INDICATOR	RESULT n= 90
toilet-to-female student ratio [7]	1:310
toilet-to-male student ratio	0:1057
urinal-to-male student ratio	0:1057
% of students who use school restroom	97%
% of students who are satisfied with school restroom	67%
% of students who said school restrooms are clean	38%
% of students who said school restrooms are accessible	46%
% of students who said school restrooms provide enough privacy	64%
% of students who wash hands at school	88%
% of students who wash their hands with soap	22%
% of students who are satisfied with school hand washing area	38%
% of students who said school hand washing area is clean	30%
% of students who said water is available	42%
% of students who said soap is available	16%
% of students who considered themselves to be "healthy"	76%
% of students who have not been absent from school due to health problems	49%

6 Source: DepEd, SY 2015-2016 Public Schools Enrollment.
7 Toilet-to-females: 3:932; toilet-to-males: 0:1,057; urinals-to-males: 0:1,057.

Figure S3.7 Health education sessions for children: contents, including sample curriculum and





Contents of Health Education Sessions

I. Overview of health education curriculum
- A. Lesson 1: What are germs?
- B. Lesson 2: What is environmental health?
- C. Lesson 3: Climate safety
- D. Lesson 4: Health promotion

II. Sample lesson plan for Lesson 2: What is environmental health?
- A. Introduction
  - 1. Describe different environments. (show photos and ask students to name places)
    - a. Colorado Rocky Mountains
    - b. Paris nightlife
    - c. Golden Gate Bridge
    - d. Egyptian pyramids
    - e. Beauty of the Philippines
      - i. Boracay beaches
      - ii. Chocolate Hills, Bohol
      - iii. Green hills of Batanes
  - 2. List 4 things that we all need to live: air, water, food, shelter.

3. What impacts do these things have on our health?
    a. Air: provides oxygen → but can cause breathing problems/allergies/asthma if...
    b. Water: provides hydration → but can cause diseases/diarrhea if...
    c. Food: provides nutrients → but can cause diseases/diarrhea if...
    d. Shelter: provides safety/security → but can cause diseases/diarrhea if...

B. Case study #1: Jane breathes in air pollution

1. Scenario: Jane is your schoolmate but from a different class section. She lives about 10 minutes away from you. She walks or takes the jeep to school. Her hobby is to go to the mall with her friends. She has had asthma ("hika" in Tagalog) since she was 6 or 7 years old. But it got worse 2 weeks ago, when she decided to stop using her face mask while riding the jeep. Now she is coughing at night, breathing loudly during exercise, and sometimes cannot catch her breath.
2. What causes air pollution? Man-made activities
    a. burning things
    b. spraying chemicals
    c. cooking with coal
    d. using equipment/vehicles that produce emissions
3. What are the health effects? Lung problems
    a. irritation/allergy
    b. asthma
    c. infections like pneumonia
4. Discussion questions
    a. Why do you think Jane stopped wearing her face mask? Was it a good idea or not? Why?
    b. What are the main causes of Jane's breathing problems? What can she do to cure her breathing problems? What can she do to prevent them from happening again in the future?
    c. If you could eliminate one of the four man-made causes of air pollution, then which one would you choose. Why?

C. Case study #2: Justin drinks "dirty" water

1. Scenario: Justin is your schoolmate but in the grade below you. He lives near the river and his hobby is playing sports (basketball, jogging). Last week he decided to stop drinking bottled water because it is expensive and he thinks he is "immune" to the germs in the tap water. Now he drinks water directly from the tap. Three days ago he started to have loose bowel movements (known as "LBM", another term for "diarrhea"). Today he missed school because he got dehydrated.
2. What causes water contamination?
    a. Natural causes: animal feces or corpses
    b. Man-made causes: urine, feces, food, garbage, chemicals
3. What are the health effects? diarrhea, fever, infection
4. Discussion questions
    a. If Justin lives near the river, then what could be some causes of water contamination?
    b. Why did he think he was "immune" to the germs in the water? Was he right or wrong? How do you know?
    c. Why did he get LBM? Why is LBM dangerous?
    d. If bottled drinking water is too expensive, then what advice would you give Justin to prevent this problem in the future?
    e. Do you think having clean drinking water is a right? Should it be free or should we have to pay for it?

D. Case study #3: Amy eats "dirty" food

1. Scenario: Amy is your "ate's" (Tagalog for "older sister") best friend and she lives just next door to you. Her hobby is watching Korean telenovelas. Yesterday after school, Amy ate fish balls cooked by a vendor who was new to your town. One hour later, she started to have a painful stomachache. At night, she was vomiting and having a high fever.
2. What causes food contamination?
    a. Natural causes: animal feces or corpses
    b. Man-made causes: urine, feces, food, garbage, chemicals
3. What are the health effects? diarrhea, vomiting, fever, infection
4. Discussion questions
    a. Do you think it is safe to eat street food? Why/why not?
    b. Why is it important to know (the vendor) who is cooking your food?
    c. Do you or your family cook fresh food more often than buying already cooked food?
    d. What should Amy do now that she is so sick? What can she do to prevent this in the future?

E. Case study #4: Bryan lives in a "dirty" house
1. Scenario: Bryan is the one of the most popular students at your school because he is very funny. He lives behind the school but is often home alone because his parents work a lot. Last weekend you visited his house and noticed that there were dirty dishes in the kitchen sink, and ants and flies near the garbage. There were also used diapers, from Bryan's baby sister, on the floor. The C.R. (known as "comfort room", another term for "restroom") smelled very badly--like old urine.
2. What causes a house to become dirty? man-made causes like lack of cleaning or improper sanitation/hygiene
3. What are the health effects? allergy, diarrhea, spread of infection
4. Discussion questions
    a. What could be the main cause of the problems in Bryan's house?
    b. Could you give Bryan advice about how to clean his house?
    c. What improvements could you make at your own house?
    d. What do you think is more important: cleanliness of oneself or cleanliness one's environment? Why?

F. Activity: work in small groups
1. Choose a topic: air, water, food, or shelter
2. Create a case study based on your school/community
3. List 2 questions you can ask the class
4. All groups share their case studies

G. Quiz game (if time permits)

III. References [1]

Note: comfort room (i.e. restroom) (C.R.); loose bowel movement (i.e. diarrhoea) (LBM).
[1] Please see References for Supplementary materials, 4-7.

Figure (Film) S3.8 "Hygiene Heroes", locally-produced educational film promoting handwashing.

Film may be viewed online using the following link:
https://drive.google.com/file/d/1T3mtebFTIuQ-e432smfp1IQdvL-VyOz4/view?usp=sharing

In response to the learning needs related to handwashing that we identified during our previous observational study [1], we created an educational film to promote handwashing. Research assistants (all of whom are Filipino college students or recent graduates) acted in the film, speaking in Tagalog. All scenes were filmed on the University of the Philippines Diliman campus. The film was about a girl who experienced nausea and vomiting after not properly washing her hands before eating her lunch. She had a dream about germs living inside someone’s body and the germs were causing an internal war. Two superheroes, named Water and Soap, teamed up to defeat the germs in battle. We showed the film to 1-3 class sections per school (about 50 students per class section) in 15 schools, and we estimate that over 1,100 children viewed the film.

---

[1] Please see References for Supplementary materials, 3.

Table S3.9 Intervention components: contents and distribution among schools in intervention arm.

Components of WaSH intervention package			
WaSH policies	Health education	Hygiene supplies	WaSH Facilities' improvements

Group	**Intervention components (by number)**															**Number of schools allocated to intervention group (A-D)**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
Intervention group A	X	X			X		X				X				X	2
Intervention group B	X		X		X			X		X				X		3
Intervention group C	X			X	X	X				X		X				4
Intervention group D	X		X		X		X		X				X			4
Total number of schools																13 [1]

Intervention component number	**Intervention type**	**Description of intervention activities**	**Rationale for intervention**
1	Policy	Policy recommendations	Lack of policy or weak enforcement
2	Education	Low-volume health education: 2 one-hour classroom sessions	Lack of knowledge or ineffective hygiene behavior
3	Education	Medium-volume health education: 3 one-hour classroom sessions	Lack of knowledge or ineffective hygiene behavior
4	Education	High-volume health education: 4 one-hour classroom sessions	Lack of knowledge or ineffective hygiene behavior
5	Education	Hygiene promotion workshop for teachers: 1 one-hour classroom session	Lack of knowledge
6	Education, hands-on activity	Soap-making workshop for parents: 1 one-hour lesson	Lack of soap, lack of knowledge, or ineffective hygiene behavior
7	Education, hands-on activity	Poster contest	Lack of knowledge
8	Education, hands-on activity	School restroom cleaning contest	Lack of cleanliness or ineffective hygiene behavior
9	Supplies [2]	Package of cleaning supplies for school janitors	Lack of supplies

10	Supplies [2]	Package of hygiene supplies for children	Lack of supplies
11	Supplies [2]	Water purifier/dispenser for drinking water	Lack of drinking water
12	Facilities	Repair of WaSH facilities	Broken WaSH facilities
13	Facilities	Installation/construction of handwashing basins	Lack of handwashing basin or running water for handwashing
14	Facilities	Installation of door locks for toilet cubicles	Lack of privacy in toilet cubicles
15	Facilities	Installation of toilets	Insufficient number of toilets

Note: water, sanitation, and hygiene (WaSH).
In Microsoft© Excel we listed the intervention components (numbers 1-15) and estimated each component's required resources (time, budget, and personnel). We then categorized the 15 intervention components into four groups (A, B, C, and D). We determined how many schools would be allocated to each intervention group based on our available resources for time, budget, and personnel. Each intervention group included the standard of care (also given to the control arm), as described below, plus low-, medium-, or high-volume[2] health education sessions and different combinations of hands-on activities, supplies, and hardware.
[1] This does not include the two schools from the control arm. The control arm received no intervention, rather the standard of care, which we defined as WaSH-related policy recommendations, a hygiene promotion workshop for teachers, and two health education sessions for children (these overlap with intervention component numbers 1, 2, and 5).
[2] See Supplementary materials, Table S3.14 for description of supplies provided.

Table S3.10 Inclusion and exclusion criteria for schools and students.

Inclusion criteria	**Exclusion criteria**
Schools	Schools
1. Classrooms are accessible during school-day hours. 2. WaSH facilities, e.g. toilets, urinals, and handwashing basins, are available on school grounds.	1. Classrooms are not accessible during school-day hours. 2. No WaSH facilities, e.g. toilets, urinals, or handwashing basins, available on school grounds.
Students	Students
1. Enrolled in school. 2. Primary school: grade 5 or 6. 3. Secondary school: grade 7, 9, or 10. 4. Able to comprehend and complete questionnaire, using tablet or smartphone, independently or with minimal assistance. 5. Able to be measured for height and weight. 6. Able to provide urine specimen.	1. Not enrolled in school. 2. Primary school: not in grade 5 or 6. 3. Secondary school: not in grade 7, 9, or 10. 4. Unable to comprehend or complete questionnaire, using tablet or smartphone, independently or with minimal assistance. 5. Unable to be measured for height and weight. 6. Unable to provide urine specimen.

Table S3.11 Questions from health literacy questionnaire for primary school children.

Number	Question
1	What is the date today?
2	When were you born?
3	How old are you?
4	What grade are you in?
5	Are you male or female?
6	What is your full address?
7	What is the telephone number of your parent/guardian?
8	What is the name of your school?
9	Did you attend this school during the last school year?
10	What are germs? They are small things that can: (choose only one answer).
11	Where can germs be found? (Read carefully the answer options and choose only one answer.)
12	What can get rid of germs? (Read carefully the answer options and choose only one answer.)
13	How can germs be transmitted from one person to another person? (Read carefully the answer options and choose only one answer.)
14	True or false: If I have germs, then I can have vomiting or diarrhea.
15	True or false: If I catch germs, then I can get an infection or sore throat.
16	True or false: Washing hands with soap and water can prevent the spread of germs.
17	When should I wash my hands with soap and water? (Read carefully the answer options and choose only one answer.)
18	How long should I wash my hands with soap and water to get rid of germs? (Choose only one answer.)
19	True or false: Washing fruits and vegetables before cooking or eating them is one way to prevent the spread of germs.
20	True or false: If the restroom is not clean, then it may contain germs which can cause illness.

Table S3.12 Questions from health literacy questionnaire for secondary school children.

Number	Question
1	What is the date today?
2	When were you born?
3	How old are you?
4	What grade are you in?
5	Are you a male or female?
6	What is your full address?
7	What is the telephone number of your parent/guardian?
8	Where do you go to school?
9	Did you attend this school during the last school year?
10	What are germs? They are small things that can: (choose only one answer).
11	Where can germs be found? (Read carefully the answer options and choose only one answer.)
12	What can get rid of germs? (Read carefully the answer options and choose only one answer.)
13	How can germs be transmitted from one person to another person? (Read carefully the answer options and choose only one answer.)
14	If I have germs, then I can have: (this/these symptom/symptoms).
15	What can prevent the spread of germs?
16	When should I wash my hands with soap and water? (Read carefully the answer options and choose one answer.)
17	How long should I wash my hands with soap and water to get rid of germs? (Choose only one answer.)
18	Why should we wash fruits and vegetables before cooking or eating them?
19	What could happen if the school restroom is not properly cleaned?
20	Why are there many germs inside the school restroom?

Table S3.13 Questions from school WaSH and household questionnaire for children.

Number	Question
1	Date
2	What is your study ID number?
3	What is your date of birth?
4	Are you male or female?
5	What is the telephone number of your parent/guardian?
6	How old are you?
7	In your opinion, are you healthy?
8	What is the name of your school?
9	Are you satisfied with the condition of the school restrooms?
10	Are the school restrooms clean?
11	Are you satisfied with the handwashing area at school?
12	Are the handwashing areas at school clean?
13	Is there a restroom in your home?
14	Do you share your restroom with another family?
15	Do you need to go outside your house to use the restroom?
16	Does your home have a toilet?
17	Does your home have a handwashing basin to wash hands?
18	Does your home have a faucet with running water?
19	Where does your family get its drinking water? (You may choose > 1 answer.)
20	Does your home have electricity?
21	What type of material is your home's floor made of? (Choose only 1 answer.)
22	Does your family have a refrigerator?
23	Does your family have its own cellphone?
24	Does your family have its own computer?
25	Does your family have its own watch/clock?
26	What types of transportation vehicles does your family have? (You may choose > 1 answer.)
27	Which mode of transportation do you most often use to go to school? (Choose only 1 answer.)
28	Does your family have its own electric fan?
29	How many adults (>= 18 years old) live in your home?
30	How many children (<= 17 years old) live in your home?
31	Is there anyone who smokes in your family?
32	Is there anyone who smokes inside the house?
33	How many adults (>= 18 years old) from your home work?
34	How many children (<= 17 years old) from your home work?
35	What is the highest level of education attained by your parent/guardian? (Choose only 1 answer.)
36	Do you have a parent/guardian who cannot read?
37	Do your parents/guardians have a physical or psychological disability that prevents them from working?
38	Do you often have enough food for everyone to eat at home?

39	Do you often have a variety of food (for example: fruits, vegetables, or meat like pork, chicken or fish) to eat at home?
40	Can you family often afford to buy food?
41	Does your family often NOT ask other people for money to buy food?
42	Does your family often cook its own food rather than buy pre-cooked food from a canteen or fast food?
43	Do you often go to sleep without feeling hunger in your stomach?
44	Do you have any questions or comments? Please write your questions or comments.

Note: identification number (ID); less than or equal to (≤); more than (>); more than or equal to (≥).

Table S3.14 Compensation for control and intervention arms.

Control arm [1] compensation package	Intervention arm compensation package	
Viewing of "Hygiene Heroes" video [2]; hand hygiene gel [3]	Group A	Control arm compensation package plus poster contest prizes [4], educational workbook [5]; ceramic water filter for drinking water (ID 8) [6], and repair and installation of toilets (ID 14).
	Group B	Control arm compensation package plus school restroom cleaning contest prizes [7], hygiene supplies [8], door locks for toilet cubicles; educational workbooks (ID 3) [5], and handwashing basins (ID 4) [9].
	Group C	Control arm compensation package plus hygiene supplies [8], school supplies (ID 2) [10], educational workbooks (ID 2,5,9) [5], soap-making materials (ID 2,5,11) [11], handwashing basins (ID 5,11) [9], and repair/installation of WaSH facilities (ID 2,5) [12].
	Group D	Control arm compensation package plus poster contest prizes [4], restroom cleaning supplies [13], educational workbook (ID 6,10,12) [5], school supplies (ID 6,10,12) [10], handwashing basins (ID 7,12) [9], gravity driven membrane filtered drinking water dispenser (ID 6,7) [14]; and menstruation hygiene supplies [15], shelving, garbage cans (ID 10).

Note: Department of Science and Technology Philippines (DOST); gravity-driven membrane (GDM); Gwangju Institute of Science and Technology (GIST); identification (number) (ID); International Environmental Research Institute (IERI); water, sanitation, and hygiene (WaSH); World Wildlife Fund (WWF).

The ID numbers refer to schools that participated in the WaSH in Manila Schools project.

[1] Rationale for compensation of control arm: 1) to meet appropriate ethical considerations regarding the handling of control participants; 2) to recompense control participants for the burden of partaking in our study, while reducing losses to follow-up; and 3) to offset some of the economic advantage received by intervention participants by providing the standard of care (i.e. WaSH-related policy recommendations, hygiene promotion workshop for teachers, and 2 health education sessions for children). Additionally, after the project was completed, we donated school supplies (as described below) to one of the two schools, having children with the most need, in the control arm and hand towels to both schools in the control arm.

[2] "Hygiene Heroes": educational video, promoting handwashing, filmed by and featuring Filipino research assistants speaking in Tagalog.

[3] Hand hygiene gel: made from raw materials and bottled by research assistants.

[4] Poster contest prizes: certificate, medal, and school supplies.

[5] Educational workbook: containing information about environmental conservation; donated by the WWF Philippines.

[6] Ceramic filter for drinking water: locally developed technology (by the University of Northern Philippines in Vigan City, Ilocos Sur) that used local materials (red clay). Able to filter tap or deep well water, at the rate of 2 litres per hour, for up to one year. Units donated by the DOST Philippines.

[7] School restroom cleaning contest prizes: snack foods (e.g. cupcakes, ice cream) and drinks.
[8] Hygiene supplies: liquid hand soap, soap dispenser, toilet paper, and paper towels.
[9] Handwashing basins: construction of freestanding or wall-mounted unit with single or multiple (2-6) handwashing basins connected to running water.
[10] School supplies: pen, pencil, notebook, colouring pencils, and reusable tote bag.
[11] Soap-making materials: gloves, plastic soap moulds, and raw materials (oil, lye, fragrance, and pink colour dye).
[12] Repair/installation of WaSH facilities: using donated or brand new toilets, urinals, and handwashing basins.
[13] Restroom cleaning supplies: all-purpose cleaner, bucket, mop, broom, dustbin, sponge, and wash cloths.
[14] GDM-filtered drinking water dispenser: donated by the IERI at the GIST, South Korea.
[15] Menstruation hygiene supplies: sanitary napkins ("pads") and panty liners.

Table S3.15 Description of training workshops provided for research assistants.

Training workshop	Instructor(s)	Contents	Instruction methods	Duration
1. For all newly hired research assistants	Research supervisor with assistance from experienced [1] research assistants	1. Introduction, icebreaker, and work documents 2. Problem background 3. Study purpose and objectives 4. Review of previous study phases 5. Research methods and materials used in school survey 6. Effective communication (including role playing) 7. Teamwork 8. Classroom management 9. Field work 101 10. Research ethics 11. Work contracts and time sheets 12. Next steps	1. Interactive lecture using PowerPoint 2. Hands-on demonstration 3. Role playing	One full day (8 hours)
2. Making soap and hand hygiene gel	Initially a research assistant (chemist); then, the research supervisor	1. Preparation of work space 2. Safe handling of raw materials 3. Step-by-step procedure for making soap and hand hygiene gel 4. Storage and clean up	1. Hands-on demonstration	One hour
3. Data processing	Research supervisor	1. Overview of data management 2. Safe handling and storage of data 3. Data security 4. Review of Excel basics 5. Data processing: cleaning and coding	1. Hands-on demonstration, with research assistants working directly on their own laptops	Full day (8 hours)

		6. Documentation of discrepancies 7. Preparation of research summary 8. Creating and formatting research portfolios		
4. Water quality testing	Research supervisor, with input from technical experts [2]	1. Field visit to dams and water treatment facilities 2. Step-by-step procedure for collecting, labeling, and transporting water samples 3. Step-by-step procedure for conducting select water quality tests in laboratory 4. Step-by-step procedure for assessing water for coliform and *E.coli* contamination	1. Hands-on demonstration	3 full days (8 hours each)

Note: Escherichia coli (E.coli); Gwangju Institute of Science and Technology (GIST); Institute of Environmental Science and Meteorology (IESM); University of the Philippines (U.P.); water, sanitation, and hygiene (WaSH).

[1] Experienced research assistants were those who had previously worked on the WaSH in Manila Schools project. We hired different teams of research assistants, with 5-8 people per team, for different phases of the project. This made it possible for experienced research assistants to help train newly hired research assistants during subsequent project phases, while maintaining continuity in the work atmosphere. The research supervisor directly managed the research team, in person, from the beginning to the end of the project.

[2] Technical experts, from the IESM, U.P. Diliman, the GIST, and Manila Water Company, Inc., voluntarily offered guidance related to water quality testing.

Table S3.16 Strategies used to promote intervention adherence.

Communication method	Person(s) contacted	Activities	Frequency
Phone call or SMS text	School principal and teachers	Confirm schedules for intervention activities	1-2 times per month, with one call or SMS text 1-2 days before scheduled activity
Face-to-face meeting in office	School principal	Discuss detailed implementation of intervention and conclusion of intervention	2 times (once at beginning and once at end of project)
Face-to-face meeting on school campus	School personnel responsible for WaSH facilities	Discuss repair or installation of toilets, urinals, or handwashing basins	2 times (once at beginning and once at end of project), with one call or SMS text 1-2 days before scheduled repair or installation
Face-to-face meeting in classroom	School children [1]	Conduct of health education sessions, poster and school restroom cleaning contests, and songwriting workshop	Various: 2-8 meetings, depending on type of intervention received
Face-to-face meeting on school campus	Other school personnel [2]: secretaries, nurse, canteen workers, security guards	Monitor progress of WaSH facilities repairs, installations, and new construction	Various: 1-4 meetings, depending on type of intervention received

Note: short message service (SMS); water, sanitation, and hygiene (WaSH).
[1] Communicating with school children: We made it a point to spend quality time with them, to pay attention to their feedback, validate their concerns, and encourage them.
[2] We made an effort to be respectful of and friendly with all school personnel because we wanted to be viewed as people who wanted to help their students, rather than as inspectors or auditors. This was important for fostering a collaborative, trusting, long-term work relationship.

References for 3A. Supplementary materials

1. UN. *Transforming our world: The 2030 Agenda for Sustainable Development*; United Nations: New York, USA, 2015.
2. DepEd. *DepEd Order No. 10, s. 26. Policy and Guidelines for the Comprehensive Water, Sanitation, and Hygiene in Schools (WinS) Program*; Department of Education: Pasig City, Philippines, 2016.
3. Sangalang, S.; Prado, N.; Lemence, A.; Cayetano, M.; Lu, J.; Valencia, J.; Kistemann, T.; Borgemeister, C. Diarrhea, Helminth Infection, Dehydration, and Malnutrition Associated with Water, Sanitation, and Hygiene Facilities and Poor Handwashing in Schools in Metro Manila, Philippines: A Cross-Sectional Study. *Am J Trop Med Hyg* (unpublished; manuscript under review).
4. DepEd. *K to 12 Curriculum Guide: Health. Grade 1 to Grade 10*; Department of Education: Pasig City, Philippines, 2012.
5. EPA. *Recipes for Healthy Kids and a Healthy Environment Kids Building a Safer and Healthier Community*; United States Environmental Protection Agency: Washington, D.C., USA, 2013.
6. U.S. National Library of Medicine. Available online: https://kidsenvirohealth.nlm.nih.gov/subtopic/004/water-pollution/009/water-cycle/ 2/3 (accessed on 8 October 2017). (as of 09/24/2020, webpage has moved to unknown location)
7. U.S. National Library of Medicine. Available online: https://kidsenvirohealth.nlm.nih.gov/subtopic/004/water-pollution/008/waterborne-diseases-&-illnesses/ 2/2 (accessed on 8 October 2017). (as of 09/24/2020, webpage has moved to unknown location)

4 SCHOOL WATER, SANITATION, AND HYGIENE (WASH) INTERVENTION TO IMPROVE MALNUTRITION, DEHYDRATION, HEALTH LITERACY, AND HANDWASHING: A CLUSTER-RANDOMISED CONTROLLED TRIAL IN METRO MANILA, PHILIPPINES

This chapter has been published as Sangalang et al. (2022) *BMC Public Health 22,* 2034; https://doi.org/10.1186/s12889-022-14398-w.

ABSTRACT

Background: The impacts of multicomponent school water, sanitation, and hygiene (WaSH) interventions on children's health are unclear. We conducted a cluster-randomized controlled trial to test the effects of a school WaSH intervention on children's malnutrition, dehydration, health literacy (HL), and handwashing (HW) in Metro Manila, Philippines.

Methods: The trial lasted from June 2017 to March 2018 and included children, in grades 5, 6, 7, and 10, from 15 schools. At baseline 756 children were enrolled. Seventy-eight children in two clusters were purposively assigned to the control group (CG); 13 clusters were randomly assigned to one of three intervention groups: low-intensity health education (LIHE; two schools, n = 116 children), medium-intensity health education (MIHE; seven schools, n = 356 children), and high-intensity health education (HIHE; four schools, n = 206 children). The intervention consisted of health education (HE), WaSH policy workshops, provision of hygiene supplies, and WaSH facilities repairs. Outcomes were: height-for-age and body mass index-for-age Z scores (HAZ, BAZ); stunting, undernutrition, overnutrition, dehydration prevalence; HL and HW scores. We used anthropometry to measure children's physical growth, urine test strips to measure dehydration, questionnaires to measure HL, and observation to measure HW practice. The same measurements were used during baseline and endline. We used multilevel mixed-effects logistic and linear regression models to assess intervention effects.

Results: None of the interventions reduced undernutrition prevalence or improved HAZ, BAZ, or overall HL scores. Low-intensity HE reduced stunting (adjusted odds ratio [aOR] 0.95; 95% CI 0.93 to 0.96), while low- (aOR 0.57; 95% CI 0.34 to 0.96) and high-intensity HE (aOR 0.63; 95% CI 0.42 to 0.93) reduced overnutrition. Medium- (adjusted incidence rate ratio [aIRR] 0.02; 95% CI 0.01 to 0.04) and high-intensity HE (aIRR 0.01; 95% CI 0.00 to 0.16) reduced severe dehydration. Medium- (aOR 3.18; 95% CI 1.34 to 7.55) and high-intensity HE (aOR 3.89; 95% CI 3.74 to 4.05) increased observed HW after using the toilet/urinal.

Conclusions: Increasing the intensity of HE reduced prevalence of stunting, overnutrition, and severe dehydration and increased prevalence of observed HW. Data may be relevant for school WaSH interventions in the Global South. Interventions may have been more effective if adherence was higher, exposure to interventions longer, parents/caregivers were more involved, or household WaSH was addressed.

Trial registration number: DRKS00021623.

Key words: child malnutrition, dehydration, health literacy, water, sanitation, and hygiene.

4.1 Background

About one in three people suffer from malnutrition globally.[1] The severity of malnutrition's consequences ranges from mild and temporary (e.g., slight weight loss) to severe and long-lasting (e.g., muscle wasting, impaired cardiorespiratory function). Malnutrition's social consequences (e.g., decreased education attainment, reduced income) are grave because of long-term impacts on communities, which may experience increasing intergenerational vulnerability to disease and deprivation.[2] Malnutrition is harmful to countries because it slows economic growth and perpetuates poverty.[3] Annually, malnutrition costs 5% of the global gross domestic product (GDP) (United States Dollar [USD] ~3.5 trillion).[4] In low- and middle-income countries (LMICs), a "double burden of malnutrition" may be found, where multiple forms of malnutrition (e.g. undernutrition and obesity) co-exist in the same household, community, or population.[1] The double burden of malnutrition, with its associated non-communicable diseases (NCDs), e.g. cardiovascular disease, diabetes, may soon overwhelm already constrained health systems and cause serious economic costs that hinder development and poverty eradication in LMICs. Such setbacks could have global consequences.

Although dehydration's consequences (e.g., dry mouth, headache) seem benign, it can become a medical emergency characterized by tachypnoea and tachycardia. In 2004, dehydration caused 518,000 hospitalizations in the United States of America (U.S.), resulting in USD 5.5 billion worth of hospital charges.[5] Very young and very old individuals have greater risks for dehydration due to impaired fluid regulation. However, school-age children should not be ignored because dehydration's negative impacts on cognitive function and mood[6] could increase school absenteeism and dropout.

Health literacy (HL) is the ability to understand concepts and practice behaviours that promote one's well-being and prevent illness.[7] Low HL is problematic because it is associated with unhealthy behaviors[8] and poor health outcomes. Handwashing (HW) knowledge has been linked to HW practice in adolescents.[9]

Interventions to promote nutrition, hydration, and HL are crucial for protecting children against diseases related to inadequate water, sanitation, and hygiene (WaSH). Examples of such diseases include diarrhoea and helminth infections, which are associated with decreased academic performance and absenteeism.[10] Without effective intervention, these diseases can lead to impaired immune function[11] and chronic diseases, e.g., anemia,[12] whose effects may last into adulthood. The social costs of chronic WaSH-related diseases include work absence, decreased wages, and productivity loss.[13] It is known that children who are malnourished and/or dehydrated may be at increased risk for cognitive impairments, which could decrease academic performance and increase school absence and dropout. Furthermore, inadequate WaSH in schools is a contributing factor of children's malnutrition, especially in the Global South. This work provides new knowledge about a comprehensive school WaSH intervention package that was comprised of policy workshops, health education, provision of hygiene supplies, and installation and repair of WaSH facilities. Specifically, it describes the intervention's effects on malnutrition, dehydration, HL, and HW. The topic is original, as no known studies have previously examined these outcomes in this setting using mixed methods. Compared with previous studies, our study provides new information about a school WaSH intervention's effects on dehydration measured by urine specific gravity, as well as hygiene-related HL. These two health outcomes have not yet been well understood in the context of school WaSH.

Most school WaSH interventions have aimed at reducing infectious diseases, though it is uncertain which interventions are effective in reducing malnutrition. HL related to HW has been studied in the elderly[14] and menstruating adolescents.[15] Few studies have assessed hygiene-related HL in schoolchildren. The purpose of our study is to promote children's health by bridging these knowledge gaps, testing a school WaSH intervention's effectiveness. Specifically, was the intervention effective in reducing malnutrition and dehydration and increasing HL and HW? We investigated the role of health education (HE) intensity, hypothesizing that high-intensity HE would be more effective than low-intensity HE in improving desired outcomes.

4.2 Methods

4.2.1 Study Design

The WaSH in Metro Manila Schools study was a cluster-randomized controlled trial (cRCT) conducted in the Philippines' National Capital Region. We used a parallel group cRCT design with unequal allocation (ratio 1:8.7) of schools to control and intervention groups (CG and IGs) to enable us to implement the intervention efficiently. We hypothesized that the intervention would improve children's HL, nutrition, hydration, and HW. We adjusted the trial design to measure group-level differences in selected outcomes by including three clusters (cities), each with different numbers of schools and children who were assessed twice, at baseline and endline. No cluster corrections were used for schools, as they were the units for different treatments. Each assessment cycle lasted about one month and was balanced between the CG and IGs to reduce confounding due to seasonal factors.

For the CG, we delivered the "standard of care" consisting of a WaSH policy workshop for teachers and two HE sessions for children. For the IGs, we randomly assigned schools to one of three arms based on the intensity (low, medium, or high) of HE. We also provided policy workshops for teachers, hygiene supplies, and WaSH facilities repairs. Instead of using a double-size CG to increase power, we made the IGs larger than the CG to increase the precision of the intervention comparison. We previously reported our study design and rationale.[16]

The study protocol was approved by the Ethics Committees of the University of Bonn, Germany (Number 216/16) (September 28, 2016), and the University of the Philippines, Manila (Number 2017–0113) (February 23, 2017).

4.2.2 Participants, study sites, and sample size

In Metro Manila, public schools have inadequate WaSH, and WaSH-related diseases are endemic. During a previous cross-sectional study conducted in March - May 2017, we measured a diarrhoea prevalence rate of 14%.[17] We selected schools in Manila, Navotas, and Quezon City, cities that are geographically and demographically representative of Metro

Manila. Schools were identified based on a complete census of schools managed by the Philippines Department of Education (DepEd). We recruited 15 public schools that previously participated in our cross-sectional study because of existing trust and cooperation with school principals and personnel. These factors facilitated communication and collaboration, which were important to us, as we wanted a long-term working relationship with schools despite limited time and resources. We offered no monetary reimbursement to participants. Instead we gave participants compensation packages comprised of school and hygiene supplies.[16]

The outcomes of HAZ and stunting prevalence are the basis of sample size estimation. It assumes a difference of 0.15 HAZ between the IG and CG, not adjusting for repeated measures within clusters, as well as a relative risk (RR) of stunting of 0.7 or smaller, with 10% prevalence in the CG. We assumed a type I error (α) of 0.05, power (1−β) of 0.8, a one-sided test for a two-sample comparison of means, and a 10% dropout after baseline. Due to limited resources, the CG was not double sized, limiting our ability to account for multiple hypothesis tests. We previously described our sample size estimation.[16] Briefly, to estimate the sample size, we considered the target population to be all the public school children in Metro Manila, where in School Year 2014–2015 a total of 2,059,447 public school children were enrolled.[18] We inflated the sample by 30% and 45% to account for nonresponse and refusal, respectively, and then inflated the sample by another 5% to account for differences in schools' enrolment sizes. The target sample size was N = 760; we enrolled 756 students at baseline and surveyed 701 students at endline eight months later (retention rate: 93%).

We previously described our multi-stage cluster sampling strategy.[16] First we recruited schools using a list of 15 schools that participated in our cross-sectional study.[17] Schools were eligible if they were public (i.e. managed by the government), had WaSH facilities available for inspection, and had no other on-going WaSH projects. Second we recruited class sections. At each school, we selected one or two class sections to obtain a target sample of ~50 students per school. To avoid interrupting classroom instruction, we recruited entire class sections as a whole rather than groups of students from multiple class sections. We did not re-recruit the students who participated in our previous cross-sectional study because a new school year had begun and caused some students to move to different class sections or schools. Third we recruited children. Participants were eligible for our study if they were in grades five, six, seven, or ten; able to complete our questionnaire independently or with minimal assistance; and able to provide relevant health data. We chose these grade levels to ensure children were developmentally mature enough to use and have perceptions about school WaSH facilities and able to actively participate in our intervention activities.

Prior to on-boarding, school principals gave written informed consent “in loco parentis”, i.e., in the place of parents, for children’s participation. We explained to children our study’s purpose and procedures, and stated that participating in our study was voluntary and that all data would be anonymized, confidential, and would not affect their school grades.

4.2.3 Randomization and masking

We have previously described how we randomly assigned clusters to treatment using Microsoft© Excel’s random number function (simple randomization).[16] Briefly, in an Excel worksheet, the names of the 13 schools were listed in the first column, wherein one row represented one school. The four IGs (A - D) were listed in the second column, wherein one row represented one IG. (We previously determined how many schools would be allocated to each group.) Schools were ranked and then assigned to groups A, B, C, or D in the third column using Excel’s random number function. IGA was known as the low-intensity health education (LIHE) group, IGB and IGD were known as the medium-intensity health education (MIHE) group, and IGC was known as the high-intensity health education (HIHE) group. The research supervisor and one research assistant (who was not involved in data collection) performed randomization and assigned schools to IGs. The research supervisor and research team enrolled participants. The investigators were unmasked, while all school principals, teachers, personnel, children, and parents, were masked to treatment assignment. It was not possible for participants to know the treatment assignment of nearby schools because any intervention materials distributed to schools did not uniquely identify treatment status.

We completed baseline surveys and then purposively assigned two schools to the CG. One school had a principal who directly asked to participate in our previous cross-sectional study, while the other school was integrated (i.e., it offered kindergarten through grade 12) and was the location of the pilot testing of our survey instruments.

4.2.4 Procedures

We designed interventions to increase children's understanding about WaSH and improve health-related behaviours, specifically HW. Our goal was to empower children to be proactive about reducing their exposure to pathogens in the environment, thereby preventing disease and promoting well-being. During formative research, we learned that there was insufficient knowledge about the health benefits of HW and adequate WaSH management. Thus, we developed an intervention strategy to increase knowledge by engaging directly with children and increasing their enthusiasm about HE and capacity for practicing healthy behaviours, as well as creating enabling environments through the provision of necessary equipment and supplies. Our educational materials were based on the existing DepEd curriculum and open educational resources from the U.S. Environmental Protection Agency and the U.S. National Library of Medicine. We report the content of HE sessions in Supplementary materials, Figure S4.1. We used findings from our cross-sectional study and baseline survey, as well as inputs from research assistants (with expertise in the local context), school principals, teachers, and janitors, and we conducted opinion polls with children. To assess whether our intervention would be acceptable and sustainable, we used participatory research and proactively engaged with stakeholders. We confirmed that intervention materials were delivered to study participants at the start of the trial and we made unannounced visits to schools to periodically assess intervention adherence. We implemented the intervention between June 2017 and March 2018 (Supplementary materials, Figure S4.2).

We previously described the four parts of the intervention.[16] Briefly, we provided: WaSH policy workshops for teachers, HE for children, hygiene supplies, and WaSH facilities improvements (Supplementary materials, Figure S4.3).

The research supervisor conducted an in-person eight-hour training workshop for research assistants before conducting baseline school surveys. We previously reported details about training methods, including the time, place, and duration of training, and teaching aids and technologies.[16] Baseline school surveys were conducted according to protocol (Supplementary materials, Figure S4.4). Eight months later, we conducted endline school surveys, using the same methodology and measuring the same outcomes assessed at baseline. We also obtained school administrative data from the DepEd and conducted two cross-sectional surveys: a demographic questionnaire for children to assess household-level risk factors and a water quality study to assess exposures to waterborne pathogens in schools and homes.

Further details about our research procedures, including contents of training workshops, intervention components, and adherence promotion strategies were previously reported.[16]

4.2.5 Outcomes

All trial outcomes were observable, measurable, pre-specified, and assessed at baseline and endline (Supplementary materials, Table S4.5). Trial outcomes were: height-for-age Z score (HAZ), body mass index-for-age Z score (BAZ), body mass index (BMI), height, and weight; prevalence of stunting (HAZ < -2), undernutrition (a composite of thinness [−3 < BAZ < −2] and severe thinness [BAZ < −3]), and overnutrition (a composite of overweight [1 < BAZ < 2] and obesity [BAZ > 2]); urine specific gravity (U_{sg}) and prevalence of any ($U_{sg} \geq 1.020$), mild ($U_{sg} = 1.020$), moderate ($U_{sg} = 1.025$), and severe dehydration ($U_{sg} = 1.030$);[19] scores for overall HL, HL about germs, and HL about HW. We calculated HAZ and BAZ using the WHO AnthroPlus (for children 5–19 years old) software (version 3.2.2., WHO, Geneva, Switzerland). We classified nutrition status using the 2007 WHO Growth Reference.[20] During initial trial registration, we erroneously omitted dehydration from our study protocol's list of outcomes; the study protocol has since been updated. We estimated HL scores via a 20-item questionnaire developed and refined by our research team. We asked children about their knowledge about general hygiene, germs, and handwashing. Examples of questions include:

"What are germs?" "True or false: If I have germs, then I can have vomiting or diarrhoea." "How long should I wash my hands with soap and water to get rid of germs?" We previously reported details about the health literacy tool and provided a sample questionnaire.[16]

We observed the adequacy of schools' WaSH facilities, assessing availability, accessibility, cleanliness, and functionality, according to guidelines from the DepEd and the Philippines Department of Health (DOH).[21,22] We report data on schools' WaSH facilities in Supplementary materials, Table S4.6.

We pilot-tested and improved data collection tools before beginning this trial and ensured the safety of participants by adhering to research protocols. No contingency plan was deemed necessary for adverse events as our intervention involved no invasive procedures or provision of medications.

We will report additional (cross-sectional) outcomes (e.g., children's self-reported health status, satisfaction with schools' WaSH facilities) and associated risk factors in a forthcoming paper. We report the sample sizes of all surveys conducted during this trial in Supplementary materials, Table S4.7.

4.2.6 Statistical analysis

The research supervisor conducted data analysis according to a pre-specified data analysis plan. We used intention-to-treat analysis, comparing each IG to the CG. We conducted descriptive analysis, pre- and post-intervention, measuring study participation, demographic characteristics, and outcomes of interest. We reported demographic characteristics and household risk factors, including food insecurity, according to study arm. For each outcome, we reported descriptive results (e.g., percentages, frequencies) for each arm, including the estimated effect size and precision. We measured frequencies and interquartile ranges (IQRs) relevant to homes' demographic makeup. Data from school inspections were summarized at the school-level by measuring the mean scores of individual facility inspections. We measured prevalence rates using contingency tables with estimates of standard error (SE) and precision.

We assessed socioeconomic status (SES) by performing a factor analysis of variables that indicated the possession of household assets, e.g., computer, cell phone, refrigerator, car. The score of the first factor was then divided into three categories using the k-means procedure. Food security status was derived from a factor analysis of variables indicating access to a secure food source, e.g., enough food is available for all members of the household; eats a variety of food; rarely has asked/begged for food; rarely has gone to sleep feeling hungry. The score of the first factor was then divided into three categories using the k-means procedure.

We used multi-level mixed effects regression models to assess intervention effects. We used two-sided tests for primary outcomes to compare study arms. Paired t-tests were used for continuous variables to calculate the mean height and weight differences. For continuous outcomes, we used multilevel mixed-effects linear regression models to estimate intervention effects with measures of precision, i.e., 95% confidence intervals (CI), and p-values. We used regression models to analyse exposure-response: $g = (E[Ai]) = \beta 0 + \beta 1Bi + \gamma Ci$, where Ai is the primary outcome of interest, g is the appropriate link function (identity for height and weight, logistic for stunting and poor HL), Bi is the continuous exposure of interest, and Ci is the vector of confounders. In linear regression models, intervention effects can be interpreted as the adjusted differences in the mean changes of the desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and desired outcome at baseline, and the parent/caregiver's education level and SES. In linear regression models that assessed school-level outcomes, we adjusted for other possible confounders, e.g. attendance in primary school, the school's MOOE budget, handwashing basin-to-student ratio, and the availability of water in the school restroom.

For binary outcomes, we used multilevel mixed-effects logistic regression and Poisson regression models. In logistic regression models, intervention effects were expressed as the odds ratio (OR) of the prevalence at endline of the desired outcome between the respective IG and CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and desired outcome at baseline, and the parent/caregiver's education level and SES. In logistic regression models that assessed school-level outcomes, we adjusted for other possible confounders, e.g. child's sex, attendance in primary school, the school's maintenance and other operating expenses (MOOE) budget, handwashing basin-to-student ratio, availability of water in school restroom. In Poisson regression models, intervention effects can be interpreted as the incidence-rate ratio (IRR) of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted all models for the children's age and sex, parent's education level, and family's SES, as well as the outcome at baseline, when appropriate. We report details of our models in Supplementary materials, Table S4.8.

To control the effect of confounding we used randomization (i.e. randomly assigning 13 schools to one of four intervention groups) and statistical methods (e.g. logistic regression models that were adjusted for possible confounding variables like age, sex, parental education, and SES.

During our assessment of missing data, if no statistically significant difference was found between children who were missing data and children who were not missing data for key outcomes, we concluded that data were missing at random (MAR), though not missing completely at random (MCAR). MAR means that, within groups defined by the observed data, all data had an equal chance of being missing and that the reason why data were missing is due to a known characteristic of the data themselves.[23] This is a less realistic occurrence in field research. Possible reasons for MAR in our study included: nonresponse or loss to follow-up due to school absence or discontinued school enrolment. We used Stata, version 15 (StataCorp, College Station, Texas, US) for all statistical analyses.

We retroactively registered our trial in the German Clinical Trials Register (DRKS) (05/08/2020; number DRKS00021623). The trial protocol is available on the DRKS's website: https://www.drks.de/drks_web/

4.2.7 Role of the funding source

The study’s funders had no role in the study design, data collection, analysis, interpretation, or writing of this article.

4.3 Results

4.3.1 Characteristics of study population

At endline, data on malnutrition and HL were available for 677 and 661 children, respectively. We used the original assignment to study arms, the CG and IGs (LIHE, MIHE, HIHE), during analysis. We based the analysis of intervention effects on the children (n=596) who provided complete health and HL data during baseline and endline (Figure 4.1). From November 2018 to January 2019, 828 children completed the demographic survey; we based our analysis of household-level covariates on this sample of children.

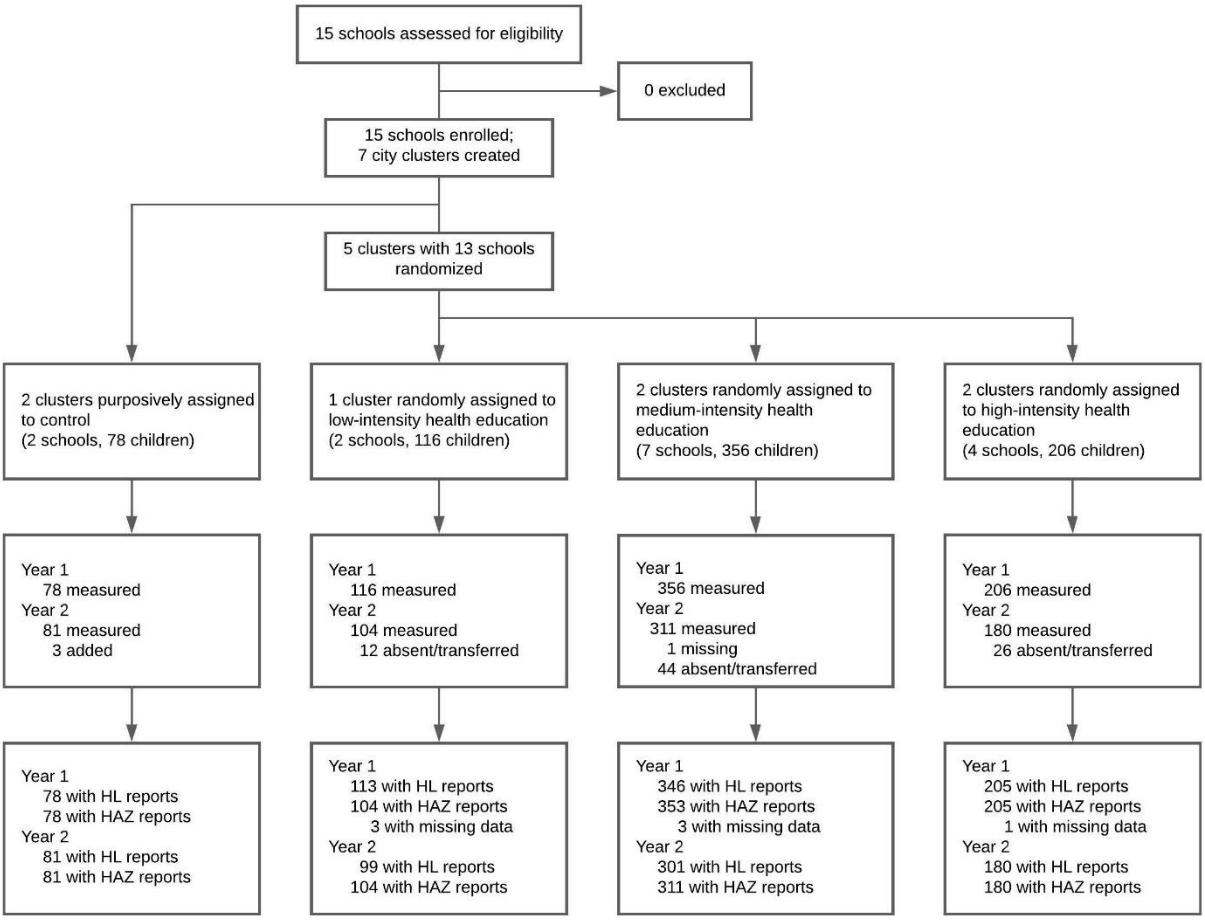


Figure 4.1 Participant flow diagram. Year 1 refers to baseline (June - August 2017) and Year 2 refers to endline (February - March 2018).

The characteristics of the children who completed the post-intervention demographic study are described in Table 4.1. At endline, over 25% of the children's families were of low SES, with about 12%of children reporting that their family shared a toilet with another family and about 8% stating they had no faucet with running water at home. The proportion of children whose parents had earned a college degree differed greatly between the CG (80%) and the IGs (ranging from 47.8% to 57%). During statistical analysis, we accounted for these differences by adjusting for parent's education level and SES. We report additional covariates in Supplementary materials, Table S4.9.

4.3.2 Change in hygiene-related HL and observed HW

The intervention did not affect mean scores for overall HL, overall knowledge about germs, or overall knowledge about HW (Table 4.2). After the intervention, the proportions of children who received a "passing" score (≥ 60%) for overall HL, overall knowledge about germs, and overall knowledge about HW increased across all study arms (Table 4.2). Compared to the CG, MIHE (aIRR 1.10; 95% CI 1.04 to 1.15) had significantly greater knowledge about using HW to prevent infection (Supplementary materials, Table S4.10). Compared to the CG, HIHE (aIRR 1.13; 95% CI 1.07 to 1.20) had significantly greater knowledge about using soap and water to remove germs from hands (Supplementary materials, Table S4.10).

The intervention negatively affected mean observed HW practice scores across all study arms: LIHE adjusted difference -0.22; 95% CI -0.31 to 0.13; MIHE adjusted difference -0.18; 95% CI -0.21 to -0.13; HIHE adjusted difference -0.51; 95% CI -0.58 to -0.44 (Table 2). The highest HW prevalence rate (37.8%) was seen in HIHE. Significantly greater odds for HW after using the toilet/urinal were seen in MIHE (adjusted odds ratio [aOR] 3.18; 95% CI 1.34 to 7.55) and HIHE (aOR 3.89; 95% CI 3.74 to 4.05).

4.3.3 Change in malnutrition status

The intervention did not affect BAZ, BMI, HAZ, or undernutrition prevalence. After the intervention, stunting prevalence decreased across all study arms (Table 4.3). The aOR of stunting was significantly lower in LIHE (aOR 0.95; 95% CI 0.93 to 0.96) compared to the CG. aORs for overnutrition decreased in all IGs. We report additional intervention effects on malnutrition and physical growth in Supplementary materials, Tables S4.11 and S4.12, respectively.

4.3.4 Change in dehydration

After the intervention, aORs and IRRs for dehydration significantly decreased in all IGs: moderate dehydration (LIHE: aOR 0.13; 95% CI 0.08 to 0.22); severe dehydration (MIHE: aIRR 0.02; 95% CI 0.01 to 0.04; HIHE: aIRR 0.01; 95% CI 0.00 to 0.16) (Table 4.4). We report intervention effects on additional hydration indicators in Supplementary materials, Table S4.13.

4.4 Discussion

We found no effects of any interventions on mean overall HL scores, BAZ, BMI, HAZ, or prevalence of undernutrition and mild dehydration. There were no intervention effects of any interventions found on schools' WaSH facilities' cleanliness, having a dry floor, having no signs of mould or damage in restrooms. No intervention effects were found on water or soap availability in school restrooms.

Meta-analyses and systematic reviews report mixed results about the impact of WaSH interventions on child growth.[24–26] Our trial findings were consistent with trials that reported school WaSH interventions had no significant effects on undernutrition. For example, a trial conducted in schools in Burkina Faso, involving 360 children, aged 8-15 years old, showed that school garden, nutrition, and WASH interventions did not decrease undernutrition prevalence. [27] A trial conducted in schools in Cambodia, Indonesia and Lao People's Democratic Republic that involved six and seven year-old children (baseline N =1,847; endline N=1,499) showed that group tooth brushing and handwashing, combined with deworming and the construction of handwashing units, did not reduce thinness prevalence.[28]

While our results are in line with the results of some studies, the results of other studies do not support our results. For example, during our trial, the intervention reduced stunting prevalence. However, a trial conducted in schools in Nepal included 682 children, aged 8-17 years old, and showed that school gardens combined with WaSH interventions did not decrease stunting prevalence.[29] During our trial, the intervention increased observed HW. However, a trial conducted in 10 intervention (average N = 420 students/school) and 10 control (average N = 449 students/school) schools in the Philippines showed that a school WaSH intervention did not improve HW practice.[30] Of note, this trial assessed HW practice via soap use ratio rather than direct observation of HW, which we assessed during our trial.

Table 4.1 Characteristics of study population by study arm.

	Control	**Low-intensity health education**	**Medium-intensity health education**	**High-intensity health education**	**Total**
Characteristics	n (%)	n (%)	n (%)	n (%)	n (%)
Cluster level (N = 3)					
Number of schools	2 (13.3)	2 (13.3)	7 (46.7)	4 (26.7)	15 (100)
Number of children	78 (10.3)	116 (15.3)	356 (47.1)	206 (27.2)	756 (100)
Grade range	5, 6	5, 6	5, 6, 7, 10	5, 6, 7	5, 6, 7, 10
School's age (in years)*, mean (SD)	69.5 (40.3)	34 (15.6)	40.6 (23.1)	51.3 (23)	46.4 (24.5)
School's annual enrolment*, mean (SD)	2126.5 (1266.4)	6017.5 (3165.7)	4032.1 (2552.2)	4389.8 (2910)	4138.1 (2557.9)
School's annual MOOE budget (in millions PhP)*, mean (SD)	1.2 (0.9)	3 (1.5)	4 (3.6)	3 (2.2)	3.2 (2.8)
School's student-to-classroom ratio*, mean (SD)	29 : 1 (12.1)	104 : 1 (19.8)	74 : 1 (18.3)	64.2 : 1 (10.8)	69.4 : 1 (25.1)
School water supply contaminated with coliform (N = 17)	0	2 (50)	2 (28.6)	3 (100)	7 (41.1)
School water supply contaminated with *E.coli* (N = 20)	1 (25)	0	1 (12.5)	1 (25)	3 (15)
Individual level (N = 756)					
Female	48 (61.5)	71 (61.2)	198 (55.6)	125 (60.7)	442 (58.5)
Child (age < 13 years)	75 (96.2)	115 (99.1)	261 (73.3)	194 (94.2)	645 (85.3)
Household factors (N= 828)	n (%)	n (%)	n (%)	n (%)	n (%)
Demographic and caregiver's characteristics					
Number of adults in home, median (IQR)	3 (2 - 4)	3 (2 - 5)	3 (2 - 5)	4 (2 - 6.5)	3 (0 - 20)
Number of children in home, median (IQR)	3 (2 - 3)	2 (2 - 3)	2 (2 - 4)	3 (2 - 4)	3 (1 - 16)
Highest level of education completed by parent/caregiver					
Secondary school and below	17 (20)	48 (42.1)	180 (46.3)	109 (47)	357 (43.1)
Above secondary school	68 (80)	66 (57.9)	209 (53.7)	122 (52.6)	470 (56.8)

Socioeconomic characteristics (N = 828)					
Socioeconomic status (SES)					
High	22 (25.9)	1 (0.9)	5 (1.3)	3 (1.3)	31 (3.7)
Middle	58 (68.2)	91 (79.8)	268 (68.9)	161 (69.4)	584 (70.5)
Low	5 (5.9)	22 (19.3)	116 (29.8)	68 (29.3)	213 (25.7)
No refrigerator	8 (9.4)	21 (18.4)	118 (30.3)	74 (31.9)	223 (26.9)
Transportation to school (most common)					
Public	22 (25.9)	2 (1.8)	101 (26)	41 (17.7)	173 (20.9)
Bicycle/pedicab	2 (2.4)	13 (11.4)	26 (6.7)	17 (7.3)	58 (7)
Bus	1 (1.2)	0	2 (0.5)	2 (0.9)	5 (0.6)
Car	26 (30.6)	1 (0.9)	8 (2.1)	6 (2.6)	41 (5)
Jeep	21 (24.7)	2 (1.8)	99 (25.4)	39 (16.8)	168 (20.3)
Tricycle/scooter/motorcycle	16 (18.8)	63 (55.3)	130 (33.4)	67 (28.9)	276 (33.3)
Walk	19 (22.4)	35 (30.7)	124 (31.9)	101 (43.5)	280 (33.8)
Food insecurity factors (N =828)					
Food security					
High	48 (56.5)	67 (58.8)	237 (60.9)	127 (54.7)	485 (58.6)
Medium	37 (43.5)	45 (39.5)	146 (37.5)	99 (42.7)	329 (39.7)
Low	0	2 (1.8)	6 (1.5)	6 (2.6)	14 (1.7)
WaSH-related factors (N = 828)					
Home has no restroom	1 (1.2)	0	7 (1.8)	4 (1.7)	12 (1.4)
Home restroom is shared with another family	14 (16.5)	7 (6.1)	41 (10.5)	32 (13.8)	95 (11.5)
Home restroom is located outside of home	4 (4.7)	4 (3.5)	32 (8.2)	23 (9.9)	63 (7.6)

Home restroom has no toilet	1 (1.2)	0	17 (4.4)	12 (5.2)	30 (3.6)
Home has no handwashing area	1 (1.2)	4 (3.5)	26 (6.7)	16 (6.9)	47 (5.7)
Home has no faucet with running water	0	6 (5.3)	37 (9.5)	21 (9.1)	64 (7.7)
Home water supply contaminated with coliform (N = 14)	0	2 (50)	0	4 (100)	6 (42.9)
Home water supply contaminated with *E.coli* (N = 14)	1 (50)	2 (50)	0	1 (25)	4 (28.6)

IQR = interquartile range. MOOE = maintenance and other operating expenses. PhP = Philippine Peso. SES = socioeconomic status. SY = school year. WaSH = water, sanitation, and hygiene. Percentages were calculated from smaller denominators than those shown at the top of the table for all variables because of missing values.

*Mean age of school = date of our first visit (30 March 2017) subtracted from school's date of operation. Mean annual enrolment during SY 2017 - 2018. Mean MOOE budget during fiscal year 2017. Mean classroom-to-student ratio = enrolment from SY 2016 - 2017 divided by the number of classrooms in 2016. Data source: Philippines Department of Education.

Table 4.2 Effect of intervention on children's hygiene-related health literacy and observed handwashing.

Outcome	**Study arm**	**Baseline**		**Endline**		**Effect of intervention (95% CI)**	**p-value**
Binary outcomes*		**n**	**%**	**n**	**%**		
Overall health literacy, passing score**	Control	73	93.6	80	98.8		
	Low-intensity education	106	93.8	99	100	1.00 (0.97, 1.03)	0.97
	Medium-intensity education	307	88.7	287	95.4	1.05 (1.02, 1.08)	p < 0.01
	High-intensity education	189	92.2	173	96.1	1.03 (1.00, 1.06)	0.02
Overall knowledge about germs, passing score	Control	74	94.9	77	95.1		
	Low-intensity education	105	92.9	98	99	1.04 (1.01, 1.07)	0.02
	Medium-intensity education	301	87	288	95.7	1.11 (1.08, 1.13)	p < 0.01
	High-intensity education	184	89.8	174	96.7	1.05 (1.03, 1.08)	p < 0.01
Overall knowledge about handwashing, passing score	Control	63	80.8	74	91.4		
	Low-intensity education	98	86.7	97	98	0.98 (0.81, 1.20)	0.88
	Medium-intensity education	281	81.2	266	88.4	1.02 (0.87, 1.19)	0.81
	High-intensity education	171	83.4	160	88.9	0.98 (0.80, 1.20)	0.88
Washed hands after using toilet/urinal***	Control			18	23.7		
	Low-intensity education			15	25.4	1.02 (0.80, 1.31)	0.84

	Medium-intensity education			15	14.2	3.18 (1.34, 7.55)	p < 0.01
	High-intensity education			40	37.8	3.89 (3.74, 4.05)	p < 0.01
Continuous outcomes****		**Mean**	**±SD**	**Mean**	**±SD**		
Mean (± SD) overall health literacy score	Control	80.3	13.9	89.1	12.4		
	Low-intensity education	86.6	13.3	95.7	7.6	-0.01 (-0.10, 0.08)	0.77
	Medium-intensity education	79.1	19	87	15.5	0.01 (-0.06, 0.08)	0.79
	High-intensity education	81.8	14.2	90.3	13.2	0.01 (-0.10, 0.11)	0.89
Mean (± SD) overall knowledge about germs score	Control	84.3	13.7	92.7	13.3		
	Low-intensity education	90.5	15.1	97.4	7.2	-0.02 (-0.09, 0.04)	0.49
	Medium-intensity education	83.5	19.8	91.2	14.7	0.02 (-0.04, 0.07)	0.53
	High-intensity education	85	15.8	93.1	12.6	0.01 (-0.04, 0.06)	0.66
Mean (± SD) overall knowledge about handwashing score	Control	73.7	20.1	83.6	16.8		
	Low-intensity education	79.9	17	92.9	15.6	0.02 (-0.14, 0.17)	0.84
	Medium-intensity education	72.3	22.6	80.6	20.8	-0.01 (-0.13, 0.11)	0.86
	High-intensity education	76.7	17.2	86	19.6	-0.005 (-0.30, 0.29)	0.98
Mean (± SD) handwashing practice score*****	Control			71.1	19.7		
	Low-intensity education			49.3	10.3	-0.22 (-0.31, -0.13)	p < 0.01
	Medium-intensity education			50.7	12.8	-0.17 (-0.21, -0.13)	p < 0.01

	High-intensity education			36.5	16.3	-0.51 (-0.58, -0.44)	$p < 0.01$

CI = confidence interval. SD = standard deviation. The p-value refers to the difference in intervention effect between the respective intervention group (IG) and the control group (CG).
*We used a multilevel mixed-effects Poisson regression model to estimate intervention effects, which can be interpreted as the incidence-rate ratio (IRR) of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and desired outcome at baseline, and the parent/caregiver's education level and socioeconomic status (SES).
**Passing score ≥ 60%.
***We used a multilevel mixed-effects logistic regression model to estimate intervention effects expressed as the odds ratio (OR) of the prevalence at endline of the desired outcome between the respective IG and CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, attendance in primary school, the school's maintenance and other operating expenses (MOOE) budget and handwashing basin-to-student ratio, and the availability of water in the school restroom.
****We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences in the mean changes of the desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and desired outcome at baseline, and the parent/caregiver's education level and SES.
*****We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences at endline of the desired outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, attendance in primary school, the school's MOOE budget and handwashing basin-to-student ratio, and the availability of water in the school restroom.

Table 4.3 Effect of intervention on children's growth and malnutrition status.

Outcome	Study arm	Baseline		Endline		Effect of intervention (95% CI)	p-value
Continuous outcomes*		Mean	±SD	Mean	±SD		
HAZ	Control	-0.07	1.3	-0.15	1.1		
	Low-intensity education	-0.59	1.4	-0.57	1.3	0.22 (-0.26, 0.70)	0.36
	Medium-intensity education	-0.85	1.1	-0.61	3.3	0.28 (-0.19, 0.75)	0.24
	High-intensity education	-0.75	1.1	-0.82	1	0.21 (-0.17, 0.58)	0.28
BAZ	Control	0.31	1.7	0.64	1.5		
	Low-intensity education	0.24	1.9	0.23	1.5	-0.18 (-0.57, 0.21)	0.37
	Medium-intensity education	-0.15	1.5	-0.12	1.5	-0.06 (-0.38, 0.26)	0.72
	High-intensity education	-0.15	1.4	-0.16	1.4	-0.10 (-0.41, 0.21)	0.53
BMI	Control	18.8	4.5	20.2	4.7		
	Low-intensity education	19	6.9	19.2	4.4	-0.78 (-1.54, -0.01)	0.05
	Medium-intensity education	18.5	3.8	18.9	3.8	-0.28 (-0.95, 0.39)	0.41
	High-intensity education	17.7	3.3	18.1	3.4	-0.33 (-0.94, 0.28)	0.29
Height (cm)	Control	143.5	11.2	147.1	9		
	Low-intensity education	140.3	10.6	145.2	9.6	0.46 (0.30, 0.63)	$p < 0.01$
	Medium-intensity education	145.5	11.2	149.1	11.2	0.98 (-0.06, 2.02)	0.07
	High-intensity education	140.5	9.3	143.8	8.6	0.57 (0.05, 1.10)	0.03
Weight (kg)	Control	39.2	12.1	44.2	12.7		
	Low-intensity education	37.5	12.6	41.3	13.2	0.08 (-0.17, 0.33)	0.53
	Medium-intensity education	39.8	11.7	42.6	11.8	0.24 (0.07, 0.41)	0.01
	High-intensity education	35.4	9.9	38	10	0.14 (-0.29, 0.57)	0.53
Binary outcomes**		n	%	n	%		

Stunting	Control	4	5.1	4	4.9		
	Low-intensity education	14	13.5	11	10.6	0.95 (0.93, 0.96)	p < 0.01
	Medium-intensity education	47	13.3	41	13.2	1.04 (0.96, 1.13)	0.29
	High-intensity education	24	11.7	19	10.5	1 (0.80, 1.25)	1
Undernutrition	Control	6	7.7	3	3.7		
	Low-intensity education	8	7.7	6	5.8	0.77 (0.09, 6.52)	0.81
	Medium-intensity education	31	8.8	24	7.7	0.93 (0.16, 5.67)	0.94
	High-intensity education	13	6.3	13	7.2	1 (0.19, 5.26)	1
Overnutrition	Control	27	34.6	36	44.4		
	Low-intensity education	32	30.8	31	29.8	0.57 (0.34, 0.96)	0.04
	Medium-intensity education	76	21.5	68	21.9	0.68 (0.37, 1.26)	0.22
	High-intensity education	44	21.4	38	21	0.63 (0.42, 0.93)	0.02

BAZ = body mass index-for-age Z score. BMI = body mass index. CG = control group. CI = confidence interval. cm = centimetre. HAZ = height-for-age Z score. IG = intervention group. kg = kilogram. SD = standard deviation.

The p-value refers to the difference in intervention effect between the respective intervention group (IG) and the control group (CG). We classified nutrition status using the 2007 WHO Growth Reference. Stunting = HAZ < −2 SD. Undernutrition = composite variable comprised of thinness (−3 < BAZ < −2) and severe thinness (BAZ < −3). Overnutrition = composite variable comprised of overweight (1 < BAZ < 2) and obesity (BAZ > 2).

*We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences in the mean changes of the desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child’s sex and age and the parent/caregiver’s education level and socioeconomic status (SES).

**We used a multilevel mixed-effects logistic regression model to estimate intervention effects, which can be expressed as the odds ratio (OR) of change in prevalence of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child’s sex and age, and the parent/caregiver’s education level and socioeconomic status SES.

Table 4.4 Effect of intervention on children's dehydration status.

Outcome	**Study arm**	**Baseline**		**Endline**		**Effect of intervention (95% CI)**	**p-value**
		n	**%**	**n**	**%**		
Severe dehydration*	Control	57	74	63	80.8		
	Low-intensity education	55	53.4	85	81.7	0.84 (0.25, 2.84)**	0.78
	Medium-intensity education	217	64.2	190	57.9	0.02 (0.01, 0.04)**	p < 0.01
	High-intensity education	116	56.6	123	68.3	0.01 (0.00, 0.16)**	p < 0.01
Moderate dehydration	Control	8	10.4	10	12.8		
	Low-intensity education	26	25.2	4	3.9	0.13 (0.08, 0.22)***	p < 0.01
	Medium-intensity education	63	18.6	42	12.8	0.73 (0.32, 1.70)***	0.47
	High-intensity education	42	20.5	23	12.8	0.62 (0.08, 5.04)***	0.66
Mild dehydration	Control	4	5.2	3	3.9		
	Low-intensity education	10	9.7	8	7.7	0.52 (0.02, 16.1)**	0.71
	Medium-intensity education	25	7.4	40	12.2	0.70 (0.04, 11.9)**	0.80
	High-intensity education	26	12.7	14	7.8	0.41 (0.03, 5.87)**	0.51

aIRR = adjusted incidence-rate ratio. aOR = adjusted odds ratio. CG = control group. CI = confidence interval. IG = intervention group. SES = socioeconomic status. Usg = urine specific gravity.

The p-value refers to the difference in intervention effect between the respective IG and the CG.

*We defined dehydration according to Usg. Any dehydration, Usg ≥ 1.020. Mild dehydration, Usg = 1.020. Moderate dehydration, Usg = 1.025. Severe dehydration, Usg = 1.030.

**We used a multilevel mixed-effects Poisson regression model to estimate intervention effects, which can be interpreted as the aIRR of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and SES.

***We used a multilevel mixed-effects logistic regression model to estimate intervention effects, which can be expressed as the aOR of change in prevalence of a desired follow-up outcome between the respective IG and CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and SES.

Yet, comparing trials should be done with caution due to differences in contexts and interventions. Possible reasons for different results reported by previous trials include: diverse intervention components and intervention delivery techniques; varying degrees of adherence to trial protocols, as well as to the intervention. Results from trials that report minimal or mixed intervention effects should not be interpreted as though school WaSH interventions should be abandoned. Rather, it is a reason to pay closer attention to the complexity of school WaSH and develop strategies that address a unique set of challenges with WaSH provision. Haque and Freeman describe these challenges as: "*a*) complex innovation and implementation requirements; *b*) limited external validity of interventions; *c*) inconsistent development sector objectives; and *d*) diverse service providers working at multiple levels".[31]

4.4.1 Effects on hygiene-related HL and HW

Mean overall HL score increased across all study arms. Of note, baseline overall HL scores were relatively high (mean 90%) to begin with. Perhaps the lack of significant effects was due to the HL questionnaire we developed, as it might have been too easy for children to answer and did not adequately assess their knowledge. Interventions with medium- and high-intensity HE significantly increased children's odds of receiving a passing score on HL overall. Our findings are consistent with other studies that demonstrated the positive impact of multiple HE sessions on children's health knowledge.[32,33]

Evidence from a 2018 systematic review showed that adolescents' HL was associated with health behaviours.[34] Thus, it is important to not ignore the value of HL when designing WaSH interventions. Strong evidence from other systematic reviews shows that children's/adolescents' HL is influenced by parents' education and SES.[35,36] A greater proportion of children from the CG reported having highly educated parents and higher SES compared to the IGs. Thus, the IGs may have been negatively impacted by having less educated parents and/or lower SES, corroborating results from previous studies.[36,37] In our study, all IGs had significantly lower mean HW practice scores compared to the CG. Although we adjusted our models for parent's education and SES, it is possible that the lower scores of the IGs were due to parents' lower education and lower SES compared to those of the CG. Children whose HW practice was assessed were randomly observed. Thus, some children could have been participants in our survey who received classroom interventions, while other children could have been non-participants who received no classroom interventions.

Medium- and high-intensity HE positively influenced observed HW prevalence, and medium-intensity HE positively increased HW with soap and using the correct HW technique. Yet low- and high-intensity HE negatively influenced children's use of the correct HW technique. These conflicting findings demonstrate the complexity of modifying health behaviours like HW. Some trials have reported that WaSH interventions increased soap usage but had no effect on HW practice.[30,38]

4.4.2 Effects on malnutrition status

Our mixed results support findings from meta-analyses and systematic reviews that reported how WaSH interventions may be inadequate in improving children's nutrition status.[24–26] Based on the results from three large-scale trials, it seems that WaSH alone may be insufficient for reducing child stunting.[39]

Although children may not be the primary decision-makers with regards to food choices at home (where parents often buy and prepare meals), they often choose what food to purchase at school and from street vendors. Thus, children must be educated so they can independently make healthy food choices. Previous studies have shown that educating children can help them make nutritious food choices.[29]

Stunting and undernutrition are persistent health problems that are likely influenced by many factors, some of which are outside the scope of schools. Nevertheless, school WaSH interventions should not be ignored. Recent trials reported that school WaSH interventions could be promising, not only for malnutrition (anaemia),[29] but also for diseases that increase risks for malnutrition like enteric diseases.[40]

4.4.3 Effects on dehydration

Low-intensity HE reduced the prevalence of moderate dehydration but greater HE intensities were needed to reduce severe dehydration. Increasing access to water at schools can increase hydration[41] and decrease dehydration prevalence[42] in children.

During a separate analysis, we compared performance on the HL questionnaire between dehydrated and non-dehydrated children. A significantly greater proportion of children with no dehydration knew when to wash their hands compared to children with mild dehydration. Hydration is important in schoolchildren because dehydration negatively affects cognitive performance,[43,44] which could lead to the practice of unhealthy behaviours.

4.4.4 Study limitations

We did not randomly assign schools to the CG. Considering the possible significant differences between schools in the CG and IG, and the smaller sample size of the CG, it was possible that no cases of less common outcomes (e.g., thinness, severe thinness) were reported. These null data made it impossible to use regression models to measure the effect of interventions after implementation. Because we did not have a double-sized CG, our ability to account of multiple hypothesis tests was limited. We did not randomly select class sections of children. Rather, school personnel selected the class sections that would be involved in our study. It is possible that the school personnel were biased towards class sections with the best academic performance, including exceptionally gifted children. Thus, the generalizability of our study findings may be limited to similar sub-populations of children, rather than the general population. We created a HL questionnaire rather than use an existing instrument. It is possible that our questionnaire had limited reliability and validity. We assessed dehydration by U_{sg} as measured by urine test strips, which depends on researchers recognizing sometimes subtle colour changes. This method may have limited reliability compared to a urine refractometer. We did not triangulate our measurements with other indicators of dehydration, e.g., physical symptoms like dry lips or subjective complaints of thirst. Because we collected demographic data at endline, we cannot be sure if social factors predisposed children to the health outcomes we measured. However, in this population the social factors were not likely to have changed much between baseline and endline. Due to limited resources, we conducted our trial in urban areas only. Similar studies in rural areas would be of interest as environmental factors and disease transmission pathways may be different in less densely populated settings.

4.4.5 Practical implications

The success of school WaSH programs depend heavily on intervention implementers (i.e. research assistants) on the one hand, and on intervention beneficiaries on the other hand. We did not assess intervention delivery or adherence in this study. However, some of our findings suggest that intervention implementation likely varied across schools. One reason for variance was a rotating team of different research assistants who implemented the intervention. Although all research assistants received training and delivered the intervention according to protocol, there were differences in their public speaking skills, competence, and enthusiasm--all of which influenced the degree to which they could engage schoolchildren and promote active learning and/or behavior change. Therefore, future intervention studies should take the role of intervention implementers into consideration by providing training and opportunities to practice skills that facilitate engagement with study participants.

Another reason for intervention delivery variance was the presence of different school factors that could not be fully controlled or accounted for, in spite of our research methodology and use of a research protocol that included standardized data collection tools. For example, some schools had very committed school principals who took ownership of WaSH management, while other schools had school principals who were less proactive. Another example is that some teachers had greater capacity to reinforce the WaSH lessons our research team delivered, while other teachers had limited capacity. Thus, future studies should consider the role that school leadership plays in WaSH management by helping school principals and teachers develop a sense of ownership and become empowered to lead improvements, while addressing barrier to change.

During our study we collaborated with multiple stakeholder groups from the education sector, local government, school staff, students' parents and families, and community partners. Future studies should seek "buy-in" from stakeholders because a sense of ownership could facilitate intervention delivery, adherence, and sustainability. Some strategies for obtaining buy-in include performing outreach to stakeholders and encouraging stakeholder participation.

During our study we assessed conventional health indicators (e.g. nutrition status) that may not change dramatically during a short study period. Relying solely on such indicators could affect how the intervention's effects would be interpreted (i.e. having little to "no" effect). Thus, it is important to assess intermediary health outcomes (e.g. HL and HW practice) which are more likely to change, even during a short time span. Therefore, future studies should consider using our approach of assessing a combination of conventional health indicators and intermediary health outcomes in order to provide a more nuanced description of intervention effects.

Based on our findings, we recommend that future interventions aimed at increasing children's HL not only focus on education intensity, but also on health-related contents and the quality of education delivery. Our experience shows the importance of using interactive teaching methods that engage students in discussion and provide opportunities for role playing healthy behaviours. Interactive teaching methods could be more effective in increasing HL compared to traditional lectures that reply only on passive learning. More research is nevertheless needed in light of our study's limitations. We recommend future studies of longer duration and the use of indicators that directly assess cognitive function (e.g. attention, memory).

4.4.6 Strengths

By assessing a wide array of indicators, including water quality, household WaSH, and food insecurity, we may help increase the understanding of malnutrition and its causes. Our trial, unlike previous ones, involved varying the intensity of HE and assessing changes in hydration. Our counting of *E. coli* and coliform colonies enabled an unbiased indicator of faecal contaminant exposure. The study design and use of standardized data collection allow study findings to be generalized to populations from similar high-need, low-resource settings in the tropics. Our findings are relevant for efficacy studies that similarly involve intensive intervention promotion.

To our knowledge, we are the first to report that a school WaSH intervention reduced overnutrition. This is important because childhood obesity is a becoming more prevalent in LMICs,[1] increasing the risk of NCDs. Despite methodological limitations, our trial provides evidence that comprehensive school WaSH interventions are able to improve direct and indirect determinants of malnutrition, such as hygiene-related HL, HW practice, and dehydration. One advantage of the tested intervention is that it can be easily replicated and quickly and affordably implemented on a larger scale in similar settings. Another advantage is the trial's potential to promote public health by providing a blueprint for evaluating the impacts of a school WaSH program. In particular, findings from our trial can be targeted to help vulnerable populations such as urban poor children and adolescents living in a tropical megacity in the Global South, where a lack of data about health, nutrition, and environmental exposures continues to hamper public health efforts. Comprehensive school WaSH could improve children's HL and HW, thereby reducing malnutrition and dehydration. In order for benefits to be maintained over the lifespan, school WaSH may likely need to be linked to parent/caregiver involvement and household WaSH.

In spite of our study's limitations, we have provided findings that contribute to the understanding of health promotion from a theoretical perspective. Specifically, our work extends and refines the Social Ecological Model (SEM) which 1) describes how behaviour is influenced by the social environment and vice versa; and 2) includes different levels of influence, e.g. individual, classroom, and school.[45,46] The SEM stipulates that people find it easier to adopt healthy behaviours when their environment is conducive to change. Thus, we implemented a multicomponent intervention package that reached individuals, classrooms, and school staff in order to improve WaSH environments in a way that facilitated proper toilet use and HW. For example, HW is influenced by self-efficacy at the individual level, social support from peers at the classroom level, and perceptions of cleanliness at the school level.

Because the SEM suggests that multiple levels of influence interact with each other, we widened our focus beyond interventions aimed only at the individual. We also addressed the classroom and school levels by targeting policies and the built environment.

4.5 Conclusions

Our trial prompts further investigation about comprehensive, yet context-specific, school WaSH interventions, examining their ability to prevent malnutrition and promote HW practice. Our findings suggest that medium- and high-intensity HE may not be more effective than low-intensity HE in improving growth or HW, and that comprehensive school WaSH interventions can reduce but may not eliminate stunting. Our trial suggests that a holistic approach to managing school WaSH, when coupled with supplementary HE aimed at engaging and empowering children, has the potential to increase children's awareness and practice of hygiene behaviours, thereby reducing infectious diseases and improving nutrition status. We recommend incorporating developmentally appropriate HE strategies (e.g., poster-making, restroom-cleaning contests, role playing, song-writing workshops) and enhancing existing school WaSH programs that promote policy enforcement, the provision of hygiene supplies, and maintenance of WaSH facilities. HE strategies targeted specifically at older children and adolescents, and outreach to parents/caregivers, are crucial for improving HL and HW and reducing malnutrition and dehydration.

Supplementary material
https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-022-14398-w#Sec22

ABBREVIATIONS

aIRR	adjusted incidence-rate ratio
aOR	adjusted odds ratio
BAZ	body mass index-for-age Z-score
BMI	body mass index
CG	control group
CI	confidence interval

cm	centimetre
cRCT	cluster-randomised controlled trial
DepEd	Philippines Department of Education
DOH	Philippines Department of Health
DRKS	Deutschen Register Klinischer Studien (German Clinical Trials Register)
E.coli	Escherichia coli
EPA	United States Environmental Protection Agency
GDP	gross domestic product
HAZ	height-for-age Z-score
HE	health education
HIHE	high-intensity health education
HL	health literacy
HW	handwashing
IG	intervention group
Inc.	incorporation (business)
IQR	interquartile range
kg	kilogram
LIHE	low-intensity health education
LMIC	low- and middle-income country
Ltd.	limited (company)
MAR	missing at random
MCAR	missing completely at random
MIHE	medium-intensity health education
MOOE	Maintenance and Other Operation Expenses
NCD	non-communicable disease
OR	odds ratio
PhP	Philippine Peso
PRC	People's Republic of China
PTA	Parent-Teacher Association

RR	relative risk
SD	standard deviation
SE	standard error
SES	socioeconomic status
SY	school year
U_{sg}	urine specific gravity
U.S.A.	United States of America
USD	United States Dollar
UN	United Nations
WaSH	water, sanitation, and hygiene
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committees of the University of Bonn, Germany (Number 216/16) (September 28, 2016), and the University of the Philippines, Manila (Number 2017–0113) (February 23, 2017). Prior to on-boarding, school principals gave written informed consent "in loco parentis", i.e., in the place of parents, for children's participation. We explained to children our study's purpose and procedures, and stated that participating in our study was voluntary and that all data would be anonymized, confidential, and would not affect their school grades. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

The datasets supporting the conclusions of this article are available upon request made with the corresponding author. Datasets will be made available in the Center for Development Research (ZEF), University of Bonn, Data Portal website, [https://daten.zef.de/geonetwork/srv/eng/catalog.search#/home]. The study protocol and data collection tools are available (open access) in the public domain at https://doi.org/10.3390/ijerph18010226. Analytic codes are included in the Supplementary Information of this article.

Competing interest

The authors declare that they have no competing interests.

Funding

This research incorporated a PhD thesis, taking place at the Center for Development Research (ZEF), University of Bonn, Germany. It was funded by SOS's PhD research grants received from: the ZEF, University of Bonn; the fiat panis Foundation; and the Katholische Akademische Ausländerdienst (KAAD). The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Authors' contributions

SOS, CB, and TK conceptualized the study and developed the methodology. SOS implemented the study, developing the intervention with NOP, MO, JCV, and RJFC. SOS, NOP, MO, RJFC, ZJO, ALGL, JCV, RMZO, and SMFM implemented the intervention. SOS, NOP, MO, RJFC, ZJO, ALGL, JCV, RMZO, SMFM, PAAS, MVJCA, MLC, and JL collected data. SOS developed the statistical analysis plan, analysed, and interpreted the data with input from CB and TK. SOS, ZJO, and ALGL verified the underlying data. NOP, ZJO, ALGL, PAAS, MVJCA, MLC, and JL assisted SOS with data processing. SOS created the tables with assistance from ALGL. SOS created the figures with assistance from ZJO. SOS drafted the first version of the manuscript. All authors reviewed and edited the manuscript, approved the final version, and accepted responsibility for publication.

Acknowledgements

We gratefully acknowledge all members of the WaSH in Metro Manila Schools project team, study participants and their parents/caregivers, school superintendents, school principals, teachers, secretaries, maintenance, security, front gate, and canteen personnel. For institutional support, the authors thank: Guenther Manske, Maike Retat-Amin, Max Voigt, Anne Grimminger, and Anna Yuen from the Doctoral Program of the ZEF, University of Bonn; Sabine Aengenendt-Baer from the ZEFc Secretariat; Alma van der Veen from the ZEF Public Relations Department; Lemnuel V. Aragones, Mylene G. Cayetano, Melanie Bantongbakal, Raian Lapresca, Mark Edward Jolejole, Paul Ezekiel Iosaria, Faye Denna, and Mikhael Cosep from the Institute of Environmental Science and Meteorology (IESM), University of the Philippines Diliman. We thank Jinky Lu from the National Institutes of Health, University of the Philippines Manila. We thank Kyoung-Woong Kim and Young-Gwang Kim from the Gwangju Institute of Science and Technology (GIST). We thank the Manila Water Company Inc. for providing technical guidance regarding water sampling. We thank Andrey Egorov from the United States Environmental Protection Agency (EPA) for his technical guidance regarding school-based WaSH surveys. We thank our team of field research assistants for their invaluable contributions: Jessie Bunao, Claire Olaivar, Paula Miclat, Genes Maylem, Erina Molia, Erika Macapagal, Guadalupe Diaz, Anton Valdellon, Patrick Tuano, Christian Ebonite, Edison Latag, Alfem Benolirao, Jergil Gavieres, Clarisse Aquino, Shelley Medina, Donrey Totanes, Cheyenne Sastrillas, Aira Galaroza, and Mark Ramos.

Authors' details

[1]Center for Development Research, University of Bonn, Bonn, Germany. [2]Department of Industrial Engineering, University of the Philippines Los Baños, Los Baños, Philippines. [3]School of Earth Sciences and Environmental Engineering, Gwangju Institute of Science and Technology, Gwangju, South Korea. [4]National Institute of Physics, College of Science, University of the Philippines Diliman, Quezon City, Philippines. [5]Philippines Department of Education, Meralco Avenue, Pasig City, Philippines. [6]College of Mass Communication, University of the Philippines Diliman, Quezon City, Philippines. [7]Marine Science Institute, University of the Philippines Diliman, Quezon City, Philippines. [8]Department of Environment Systems, University of Tokyo, Kashiwa, Chiba, Japan. [9]National Institute of Geological Sciences, University of the Philippines Diliman, Quezon City, Philippines. [10]School of Medicine, Far Eastern University - Nicanor Reyes Medical Foundation, Quezon City, Philippines. [11]School of Social Sciences, Ateneo de Manila University, Quezon City, Philippines. [12]Nutrition Research Institute, Philippines Department of Science and Technology, Taguig, Philippines. [13]School of Diplomacy and Governance, De La Salle - College of Saint Benilde, Manila, Philippines. [14]Department of Psychology, University of the Philippines Diliman, Quezon City, Philippines. [15]Institute of Hygiene and Public Health, University of Bonn, Bonn, Germany.

References

1. World Health Organization. The double burden of malnutrition. Policy brief. Available: https://apps.who.int/iris/bitstream/handle/10665/255413/WHO-NMH-NHD-17.3-eng.pdf?ua=1 (accessed January 19, 2022).

2. Martorell R, Zongrone A. Intergenerational Influences on Child Growth and Undernutrition. Paediatr Perinat Epidemiol 2012; 26: 302–14.
3. Adair LS, Fall CH, Osmond C, et al. Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. The Lancet 2013; 382: 525–34.
4. Food and Agriculture Organization, editor. Food systems for better nutrition. The state of food and agriculture. Rome, 2013. Available: http://www.fao.org/3/i3300e/i3300e.pdf (accessed January 29, 2022).
5. Kim S. Preventable Hospitalizations of Dehydration: Implications of Inadequate Primary Health Care in the United States. Ann Epidemiol 2007; 17: 736.
6. Masento NA, Golightly M, Field DT, Butler LT, Reekum CM van. Effects of hydration status on cognitive performance and mood. Br J Nutr 2014; 111: 1841–52.
7. United States Institute of Medicine Committee on Health Literary; Nielsen-Bohlman L, Panzer AM, Kindig DA, editors. What Is Health Literacy? National Academies Press (US), 2004. Available: https://www.ncbi.nlm.nih.gov/books/NBK216035/ (accessed January 19, 2022).
8. Svendsen MT, Bak CK, Sørensen K, et al. Associations of health literacy with socioeconomic position, health risk behavior, and health status: a large national population-based survey among Danish adults. BMC Public Health 2020; 20. DOI:10.1186/s12889-020-08498-8.
9. Riiser K, Helseth S, Haraldstad K, Torbjørnsen A, Richardsen KR. Adolescents' health literacy, health protective measures, and health-related quality of life during the Covid-19 pandemic. PLOS ONE 2020; 15: e0238161.
10. Pabalan N, Singian E, Tabangay L, Jarjanazi H, Boivin MJ, Ezeamama AE. Soil-transmitted helminth infection, loss of education and cognitive impairment in school-aged children: A systematic review and meta-analysis. PLoS Negl Trop Dis 2018; 12. DOI:10.1371/journal.pntd.0005523.

11. van Riet E, Hartgers FC, Yazdanbakhsh M. Chronic helminth infections induce immunomodulation: Consequences and mechanisms. Immunobiology 2007; 212: 475–90.
12. Donohue RE, Cross ZK, Michael E. The extent, nature, and pathogenic consequences of helminth polyparasitism in humans: A meta-analysis. PLoS Negl Trop Dis 2019; 13. DOI:10.1371/journal.pntd.0007455.
13. Lenk EJ, Redekop WK, Luyendijk M, Rijnsburger AJ, Severens JL. Productivity Loss Related to Neglected Tropical Diseases Eligible for Preventive Chemotherapy: A Systematic Literature Review. PLoS Negl Trop Dis 2016; 10: e0004397.
14. Or PP-L, Wong BY-M, Chung JW-Y. To investigate the association between the health literacy and hand hygiene practices of the older adults to help them fight against infectious diseases in Hong Kong. Am J Infect Control 2020; 48: 485–9.
15. Holmes K, Curry C, Sherry, et al. Adolescent Menstrual Health Literacy in Low, Middle and High-Income Countries: A Narrative Review. Int J Environ Res Public Health 2021; 18: 2260.
16. Sangalang SO, Medina SAJ, Ottong ZJ, et al. Protocol for a Trial Assessing the Impacts of School-Based WaSH Interventions on Children's Health Literacy, Handwashing, and Nutrition Status in Low- and Middle-Income Countries. Int J Environ Res Public Health 2021; 18. DOI:10.3390/ijerph18010226.
17. Sangalang SO, Prado NO, Lemence ALG, Cayetano MG, Lu JLDP, Valencia JC, et al. Diarrhoea, malnutrition, and dehydration associated with school water, sanitation, and hygiene in Metro Manila, Philippines: A cross-sectional study. Sci Total Environ 2022 Sep 10;838(Pt 2):155882.
18. Philippines DepEd. Elementary and junior and senior high school enrollment, school years 2014–2019 (dataset).
19. Pagana KD, Pagana TJ. Mosby's diagnostic and laboratory test reference [12th ed. St. Louis, Mo.: Elsevier Mosby, 2015.

20. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007; 85: 660–7.
21. Philippines Department of Education (DepEd). Policy and guidelines for the comprehensive water, sanitation, and hygiene in schools (WINS) program. DepEd Order No. 10, s2016. Available: https://www.deped.gov.ph/wp-content/uploads/2016/02/DO_s2016_10-1.pdf (accessed January 29, 2022).
22. Philippines Department of Health. Implementing Rules and Regulations of Chapter VI, "School Sanitation and Health Services", of the Code on Sanitation of the Philippines (P.D. 856). Manila, Philippines: Department of Health, 1998. Available: https://www.doh.gov.ph/sites/default/files/publications/Chapter_6_School_Sanitation_and_Health_Services.pdf (accessed October 6, 2021).
23. Little R, Rubin DB. Statistical Analysis with Missing Data [3rd Edition] Hoboken, New Jersey, U.S.A.: John Wiley & Sons, Inc. 2020. Available: https://www.wiley.com/en-us/Statistical+Analysis+with+Missing+Data%2C+3rd+Edition-p-9780470526798 (accessed May 31, 2021).
24. Gera T, Shah D, Sachdev HS. Impact of Water, Sanitation and Hygiene Interventions on Growth, Non-diarrheal Morbidity and Mortality in Children Residing in Low- and Middle-income Countries: A Systematic Review. Indian Pediatr 2018; 55: 381–93.
25. Bekele T, Rawstorne P, Rahman B. Effect of water, sanitation and hygiene interventions alone and combined with nutrition on child growth in low and middle income countries: a systematic review and meta-analysis. BMJ Open 2020; 10: e034812.
26. Dangour AD, Watson L, Cumming O, et al. Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. Cochrane Database Syst Rev 2013; : CD009382.
27. Erismann S, Diagbouga S, Schindler C, et al. School Children's Intestinal Parasite and Nutritional Status One Year after Complementary School Garden, Nutrition, Water, Sanitation, and Hygiene Interventions in Burkina Faso. Am J Trop Med Hyg 2017; 97: 904–13.

28. Duijster D, Monse B, Dimaisip-Nabuab J, et al. 'Fit for school' - a school-based water, sanitation and hygiene programme to improve child health: Results from a longitudinal study in Cambodia, Indonesia and Lao PDR. BMC Public Health 2017; 17: 302.
29. Shrestha A, Schindler C, Odermatt P, et al. Nutritional and health status of children 15 months after integrated school garden, nutrition, and water, sanitation and hygiene interventions: a cluster-randomised controlled trial in Nepal. BMC Public Health 2020; 20: 158.
30. Duijster D, Buxton H, Benzian H, Dimaisip-Nabuab J, Monse B, Volgenant C, et al. Impact of a school-based water, sanitation and hygiene programme on children's independent handwashing and toothbrushing habits: a cluster-randomised trial. Int J Public Health 2020 Dec;65(9):1699–709.
31. Haque SS, Freeman MC. The Applications of Implementation Science in Water, Sanitation, and Hygiene (WASH) Research and Practice. Environmental Health Perspectives 2021; 129(6):065002.
32. Stinson JN, Lalloo C, Hundert AS, et al. Teens Taking Charge: A Randomized Controlled Trial of a Web-Based Self-Management Program With Telephone Support for Adolescents With Juvenile Idiopathic Arthritis. J Med Internet Res 2020; 22: e16234.
33. Kebede Y, Abebe L, Alemayehu G, Sudhakar M, Birhanu Z. School-based social and behavior change communication (SBCC) advances community exposure to malaria messages, acceptance, and preventive practices in Ethiopia: A pre-posttest study. PloS One 2020; 15: e0235189.
34. Fleary SA, Joseph P, Pappagianopoulos JE. Adolescent health literacy and health behaviors: A systematic review. J Adolesc 2018; 62: 116–27.
35. Stormacq C, Van den Broucke S, Wosinski J. Does health literacy mediate the relationship between socioeconomic status and health disparities? Integrative review. Health Promot Int 2019; 34: e1–17.
36. Mao Y, Xie T, Zhang N. Chinese Students' Health Literacy Level and Its Associated Factors: A Meta-Analysis. Int J Environ Res Public Health 2020; 18. DOI:10.3390/ijerph18010204.

37. Paakkari L, Torppa M, Mazur J, et al. A Comparative Study on Adolescents' Health Literacy in Europe: Findings from the HBSC Study. Int J Environ Res Public Health 2020; 17: 3543.
38. Biran A, Schmidt W-P, Varadharajan KS, et al. Effect of a behaviour-change intervention on handwashing with soap in India (SuperAmma): a cluster-randomised trial. Lancet Glob Health 2014; 2: e145-154.
39. Cumming O, Arnold BF, Ban R, et al. The implications of three major new trials for the effect of water, sanitation and hygiene on childhood diarrhea and stunting: a consensus statement. BMC Med 2019; 17. DOI:10.1186/s12916-019-1410-x.
40. Chard AN, Trinies V, Moss DM, et al. The impact of school water, sanitation, and hygiene improvements on infectious disease using serum antibody detection. PLoS Negl Trop Dis 2018; 12: e0006418.
41. Trinies V, Chard AN, Mateo T, Freeman MC. Effects of Water Provision and Hydration on Cognitive Function among Primary-School Pupils in Zambia: A Randomized Trial. PloS One 2016; 11: e0150071.
42. Chard AN, Trinies V, Edmonds CJ, Sogore A, Freeman MC. The impact of water consumption on hydration and cognition among schoolchildren: Methods and results from a crossover trial in rural Mali. PLOS ONE 2019; 14: e0210568.
43. Bar-David Y, Urkin J, Kozminsky E. The effect of voluntary dehydration on cognitive functions of elementary school children. Acta Paediatr Oslo Nor 1992 2005; 94: 1667–73.
44. Fadda R, Rapinett G, Grathwohl D, et al. Effects of drinking supplementary water at school on cognitive performance in children. Appetite 2012; 59: 730–7.
45. Bronfenbrenner U. Toward an experimental ecology of human development. American Psychologist 1977; 32(7), 513–531. https://doi.org/10.1037/0003-066X.32.7.513
46. Mcleroy K, Bibeau D, Steckler A, Glanz K. An Ecology Perspective on Health Promotion Programs. Health education quarterly 1988 Feb 1;15:351–77.

4.A Supplementary Materials
https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-022-14398-w#Sec22

Contents

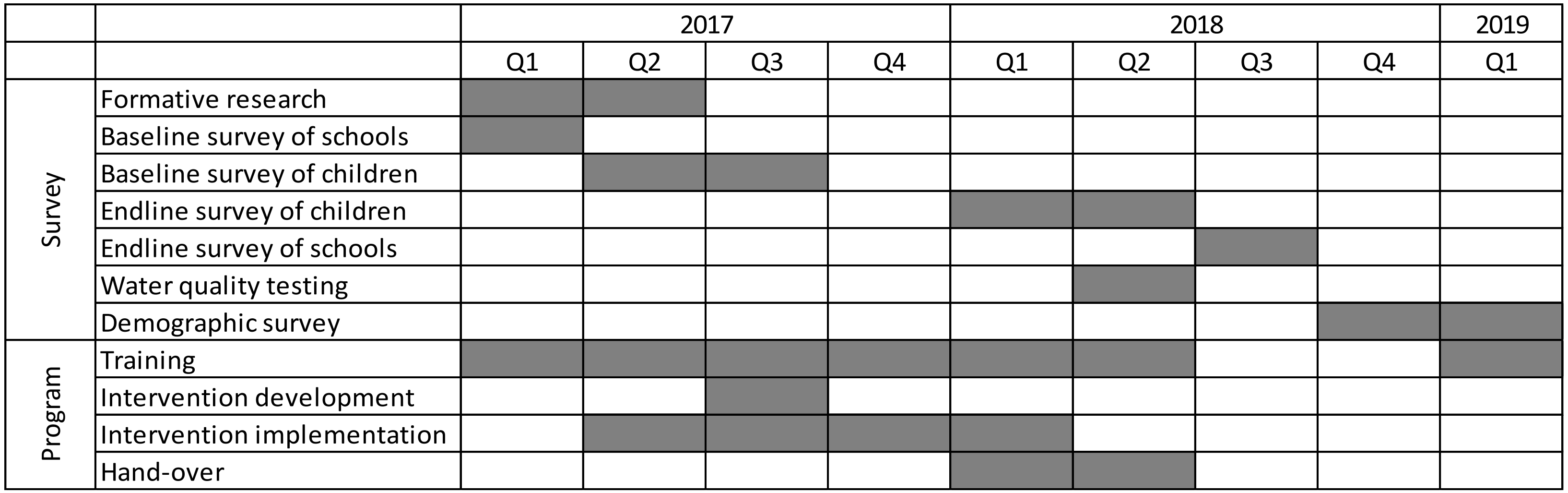
Figure S4.1 Health education session content by intervention arm.

Study arm	**Session number**			
	1	**2**	**3**	**4**
Control	X			X
LIHE	X			X
MIHE	X	X		X
HIHE	X	X	X	X

1. What are germs? 1.1 What are germs? 1.1.1 Symptoms of infection 1.2 What do germs look like? 1.2.1 Bacteria: *E. coli* 1.2.2 Virus: influenza 1.2.3 Fungi: *Candida albicans* 1.3 Where can germs be found? 1.3.1 Human body 1.3.2 Food & water 1.3.3 Animals 1.3.4 Environment: school restroom 1.4 What can get rid of germs? 1.5 What are the five steps of proper handwashing?	**2. What is environmental health?** 2.1 Elements of environment 2.2 Importance of water 2.3 Bodies of water in the Philippines 2.4 Water cycle 2.5 Water pollution 2.6 Water & health 2.7 Consequences of unclean water
3. Climate safety 3.1 Safe sun exposure 3.1.1 What is the sun? 3.1.2 Three things that the sun gives us 3.1.3 Too much sun exposure 3.1.4 Sun protection 3.1.5 Dangers of skin "whitening" 3.2 Natural disasters preparedness 3.2.1 Types of natural disasters 3.2.2 Common natural disasters in the Philippines 3.2.3 Why the Philippines is at high risk 3.2.4 How to survive 3.3 What is climate change?	**4. Health promotion** 4.1 What does "health" mean? 4.2 Healthy habits 4.2.1 Hygiene 4.2.2 Exercise 4.2.3 Sleep 4.2.4 Screen time 4.3 Nutrition 4.3.1 Food pyramid 4.3.2 Balanced diet 4.3.3 Which dish should you eat? 4.3.4 Malnutrition 4.4 Disease prevention 4.4.1 Vaccines 4.4.2 Avoid stress 4.4.3 Adequate WaSH

HIEH = high-intensity health education. LIHE = low-intensity health education. MIHE = moderate-intensity health education.

Figure S4.2: Project timeline.



Q = quarter. WaSH = water, sanitation, and hygiene.
Formative research: pilot testing of data collection tools; cross-sectional study about association between school WaSH and children's diarrhoea, malnutrition, dehydration (N = 1,558); cross-sectional study about household WaSH and parents' perceptions about WaSH and experience with food insecurity.
Survey of schools: data from school principals via interview and from school WaSH facilities via inspection.
Survey of children: data from children via questionnaire and observation.
Training: different research teams (comprised of 4 - 8 investigators) were hired and trained for nearly all phases of the project. The only constant was the research supervisor (i.e. the corresponding author). We have reported the contents of our training modules previously.[16]
Intervention development and implementation: Please refer to the Supplementary Materials of our study protocol.[16]

Hand-over: provision of printed research portfolio to school principal. Portfolio included summary of research activities, results, and recommendations. Provision of certificate of participation to school principal and token of appreciation for study participants. We provided no monetary reimbursement; we reported compensation for study participants previously.[16]

Figure S4.3 Summary of school WaSH intervention components.

WaSH policies

- Rationale: to address lack of policy or weak policy enforcement
- Intervention activities: printed research portfolios containing summary of survey findings and policy recommendations; one-hour workshops for school teachers[1]

Health education

- Rationale: lack of knowledge or ineffective hygiene behavior
- Intervention activities: between two and four one-hour HE sessions[2], poster-making contests, restroom cleaning contests, songwriting workshops, viewings of eight-minute educational video, "Hygiene Heroes"[3]

WaSH supplies

- Rationale: lack of water for drinking & HW, lack of soap, lack of cleanliness in restrooms, children's lack of satisfaction with restrooms
- Intervention activities: package of cleaning supplies for school janitors[4], package of hygiene supplies for children[5], water purifier/dispenser for drinking water[6]

WaSH facilities improvements

- Rationale: broken or insufficient WaSH facilities; lack of privacy in toilet cubicles
- Intervention activities: repair of WaSH facilities, installation/construction of HW basins & toilets, installation of door locks for toilet cubicles

DepEd = Philippines Department of Education. HE = health education. HIHE = high-intensity health education. HL = health literacy. HW = handwashing. LIHE = low-intensity health education. MIHE = medium-intensity health education. SDG = Sustainable Development Goal. UN = United Nations. WaSH = water, sanitation, and hygiene.

[1]We provided school principals a printed research portfolio with recommendations for enforcing the DepEd's existing WaSH policies. We conducted one-hour hygiene promotion workshops for teachers to demonstrate the need to improve WaSH in schools, in line with the UN's SDG 6, related to WaSH, and to comply with the DepEd's Order No. 10, related to WaSH in schools.

[2]We created a HE package based on HL predictors, facilitators, and barriers. Research assistants delivered between two and four one-hour HE sessions to children based on treatment assignment. Participants in the LIHE group received two sessions, while those in the MIHE and HIEH groups received three and four sessions, respectively. Each HE session comprised of an interactive verbal presentation accompanied by Microsoft© PowerPoint slides, class discussion, and trivia game. To increase children's interest in WaSH, we used mixed methods as described in our study protocol.[16]

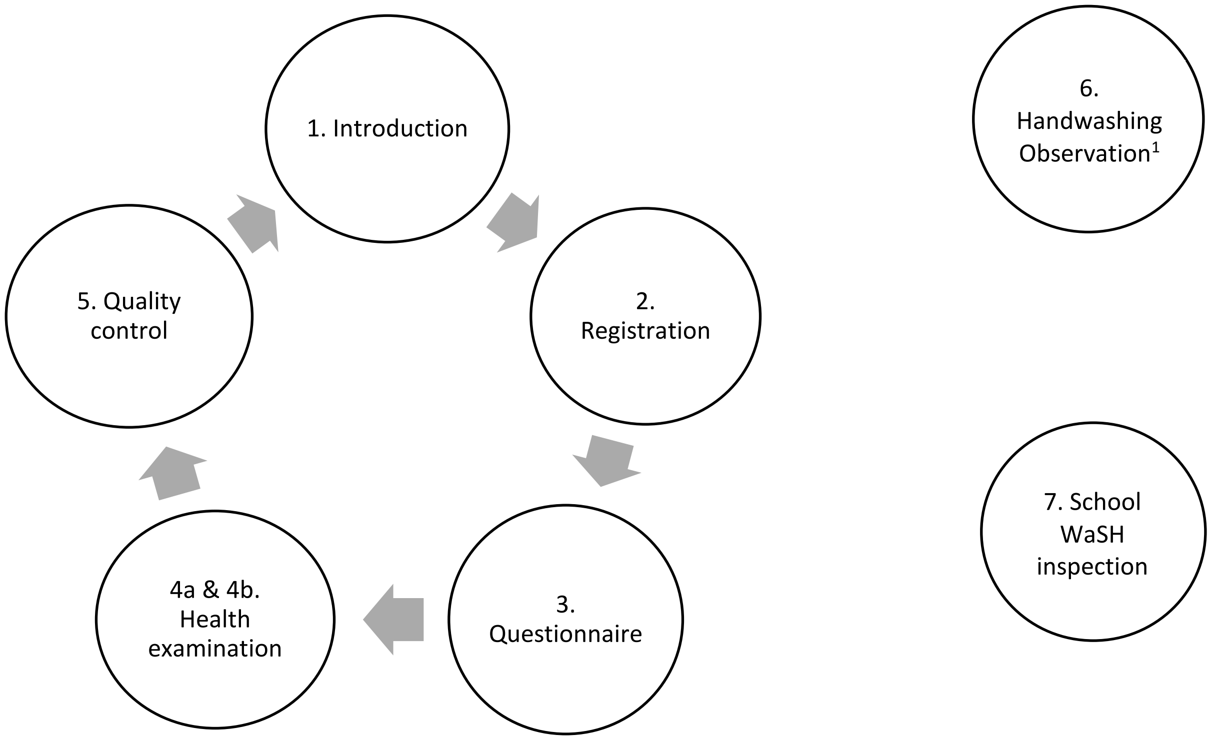
[3]"Hygiene Heroes", is a Tagalog (Filipino) language educational video about the importance of proper HW. It was developed by the research team and features research assistants in all acting roles. A copy of the video is available upon request from the corresponding author.

[4]Cleaning supplies, e.g. brooms, mops, dustpans, all-purpose cleaner, sponges, wash cloths.

[5]Hygiene supplies, e.g. liquid and bar hand soap, wall-mounted dispensers for liquid soap, menstruation pads, shelving (for storing supplies).

[6]Drinking water with ceramic filter donated by the Philippines Department of Science and Technology. Drinking water with gravity driven membrane donated by the Gwangju Institute of Science and Technology.

Figure S4.4 Summary of conduct of baseline school survey.



Step	Station	Activities
1	Introduction	After entering the classroom, research assistants introduced themselves to the teacher and children. They explained, in Tagalog (Filipino) language, the study's purpose, objectives, and procedures.
2	Registration	Children were assigned a unique study ID number and given a set of 3 tickets labelled with their study ID number. The three tickets corresponded to three research stations: 1) HL questionnaire, 2) urine testing, and 3) height and weight measurement. Children were instructed to give their tickets to the appropriate research assistant at each station after providing the relevant data.
3	Questionnaire	Children completed the HL questionnaire using the QuickTapSurvey© app (Formstack LLC, Fishers, Indiana, U.S.A.) installed on password-protected tablets and smartphones. Children answered the questionnaire independently and privately, away from the view of their classmates. Research assistants verified the completion of each child's questionnaire .
4	a. Height and weight	Research assistants measured children's standing height (to the nearest cm), without shoes, using a tape measure attached to the wall of the school building. We measured children's weight (to the nearest 0.1 kg), without shoes or any items inside their pockets, using a digital weighing scale (EKS Asia Ltd., Hong Kong, Special Administrative Region of the People's Republic of China).
	b. Urine	Research assistants asked children to put their freshly collected urine specimen inside a plastic cup that was labelled with their study ID number. Point-of-care urinalysis was performed per protocol with urine test strips (Insight Urinalysis Reagent Strips, Acon Laboratories Inc., San Diego, California, U.S.A.). We interpreted the urinalysis results by comparing the colour changes displayed on the urine test strip to the manufacturer-provided urinalysis interpretation guide.

5	Quality control	At the end of the school survey, but prior to leaving the school campus, we counted the number of responses saved in the tablets and smartphones. We verified that this number matched the total number of tickets collected from all three research stations (HL questionnaire, height and weight, and urine stations).
6	Handwashing observation	We conducted unannounced handwashing observations to see if children washed their hands after using the toilet or urinal, and if they used the correct handwashing technique and for the correct duration of time.
7	School WaSH inspection	We completed school restroom inspection checklists and interviewed school principals or representatives about school WaSH policies and perceptions about WaSH.

cm = centimetre. ID = identification. kg = kilogram. LLC = limited liability company. Ltd. = limited company. U.S.A. = United States of America. WaSH = water, sanitation, and hygiene.

[1]Steps 6 and 7 are not included in the main process diagram to indicate that they were not necessarily completed during same school visit as steps 1−5.

Table S4.5 Trial outcomes, expected results, contents of health education intervention, and training provided to research assistants.

Outcome	Description of outcome	Expected results	Contents of health education intervention	Training provided
Outcome 1 (Primary outcome)	Change in children's knowledge about WaSH (e.g., handwashing, germs, infection prevention)	Children will know: • when to wash their hands. • how long to wash their hands. • how to prevent infection by washing their hands. • that germs can be removed by washing hands with soap and water. • symptoms of infection. Improvement in health literacy scores specific to germs, infection prevention, and handwashing, among children in the high-intensity HE arm.	**1. What are germs?** **1.1 What are germs?** **1.1.1 Symptoms of infection** 1.2 What do germs look like? 1.2.1 Bacteria: E. coli 1.2.2 Virus: influenza 1.2.3 Fungi: Candida albicans **1.3 Where can germs be found?** **1.3.1 Human body** **1.3.2 Food & water** **1.3.3 Animals** **1.3.4 Environment: school restroom** **1.4 What can get rid of germs?** **1.5 What are the five steps of proper handwashing?**	Lecture, demonstration, small group work, practice with public speaking, child-friendly communication, and classroom management
Outcome 2 (Primary outcome)	Change in nutritional status	Improvement in BAZ and HAZ and decreased prevalence of stunting, undernutrition, and overnutrition among children in the high-intensity HE arm.	4. Health promotion 4.1 What does "health" mean? 4.2 Healthy habits 4.2.1 Hygiene 4.2.2 Exercise 4.2.3 Sleep 4.2.4 Screen time **4.3 Nutrition** **4.3.1 Food pyramid**	Lecture, small group work, practice with public speaking, child-friendly communication, and classroom management

			4.3.2 Balanced diet **4.3.3 Which dish should you eat?** **4.3.4 Malnutrition** 4.4 Disease prevention 4.4.1 Vaccines 4.4.2 Avoid stress 4.4.3 Adequate WaSH	
Outcome 3	Change in hydration status	Improvement in urine specific gravity among children in the high-intensity HE arm.	2. What is environmental health? 2.1 Elements of environment **2.2 Importance of water** 2.3 Bodies of water in the Philippines 2.4 Water cycle 2.5 Water pollution **2.6 Water & health** 2.7 Consequences of unclean water	Lecture, small group work, practice with public speaking, child-friendly communication, and classroom management
Outcome 4	Change in handwashing practice	Improvement of observed handwashing prevalence in intervention arms.	1. What are germs? 1.1 What are germs? 1.1.1 Symptoms of infection 1.2 What do germs look like? 1.2.1 Bacteria: E. coli 1.2.2 Virus: influenza 1.2.3 Fungi: Candida albicans 1.3 Where can germs be found? 1.3.1 Human body 1.3.2 Food & water 1.3.3 Animals 1.3.4 Environment: school restroom **1.4 What can get rid of germs?**	Lecture, demonstration, small group work, practice with public speaking, child-friendly communication, and classroom management

			1.5 What are the five steps of proper handwashing?	
Outcome 5	Change in schools' WaSH adequacy	Improvement of observed adequacy of WaSH conditions among schools in intervention arms.	N/A	N/A

BAZ = body mass index-for-age Z score. HAZ = height-for-age Z score. HE = health education. WaSH = water, sanitation, and hygiene. Bold indicates special emphasis given to this topic during health education intervention(s). Additional information can be found in the Supplemental Material Sangalang et al., 2021.

Table S4.6 Effect of intervention on the adequacy of schools' WaSH facilities.

Outcome*	Study arm	Baseline mean +- SD	Endline mean +- SD	Effect of intervention (95% CI)	p-value
Restroom is clean	Control	0.5 (0.71)	0.39 (0.15)		
	Low-intensity education	0.29 (0.06)	0 (-)	-0.23 (-1, 0.54)	0.57
	Medium-intensity education	0.25 (0.39)	0.33 (0.27)	0.16 (-0.61, 0.93)	0.69
	High-intensity education	0.15 (0.18)	0.19 (0.14)	0.15 (-0.47, 0.77)	0.64
Restroom has water available	Control	0.75 (0.35)	0.93 (0.10)		
	Low-intensity education	0.69 (0.44)	1 (-)	-0.18 (-0.53, 0.17)	0.32
	Medium-intensity education	0.70 (0.19)	0.90 (0.19)	0.02 (-0.26, 0.29)	0.90
	High-intensity education	0.71 (0.21)	0.89 (0.21)	0.01 (-0.31, 0.33)	0.97
Restroom floor is dry	Control	0.50 (0.71)	0.31 (0.44)		
	Low-intensity education	0.13 (0.18)	0 (-)	0.19 (-0.18, 0.55)	0.32
	Medium-intensity education	0.12 (0.14)	0.08 (0.17)	0.15 (-0.14, 0.44)	0.31
	High-intensity education	0.07 (0.13)	0.08 (0.15)	0.20 (-0.13, 0.53)	0.24
Restroom has no signs of mould	Control	0.50 (0.71)	0.43 (0.61)		
	Low-intensity education	0.06 (0.09)	1 (-)	1.07 (-0.75, 2.89)	0.25
	Medium-intensity education	0.23 (0.27)	0.71 (0.39)	0.53 (-0.97, 2.03)	0.49

	High-intensity education	0.61 (0.28)	0.27 (0.38)	-0.27 (-1.79, 1.25)	0.73
Restroom has no flies	Control	0.92 (0.12)	1 (0)		
	Low-intensity education	0.77 (0.15)	1 (-)	0.25 (0.09, 0.41)	p < 0.01
	Medium-intensity education	1 (0)	0.75 (0.41)	-0.35 (-0.90, 0.19)	0.20
	High-intensity education	1 (0)	0.87 (0.25)	-0.21 (-0.51, 0.08)	0.16
All toilets flush	Control	0.50 (0.71)	0.80 (0.08)		
	Low-intensity education	0.52 (0.21)	0 (-)	-0.97 (-2.06, 0.11)	0.08
	Medium-intensity education	0.17 (0.25)	0.55 (0.45)	0.03 (-0.79, 0.85)	0.94
	High-intensity education	0.17 (0.24)	0.50 (0.40)	0.03 (-0.79, 0.85)	0.94
Restroom has waste disposal bin available	Control	0.52 (0.50)	0.59 (0.23)		
	Low-intensity education	0.06 (0.09)	0.50 (-)	0.43 (0.05, 0.81)	0.03
	Medium-intensity education	0.41 (0.38)	0.36 (0.38)	-0.13 (-0.44, 0.17)	0.40
	High-intensity education	0.15 (0.18)	0.12 (0.19)	-0.09 (-0.45, 0.26)	0.61
Restroom has no graffiti	Control	0.33 (0.24)	0.81 (0.27)		
	Low-intensity education	0.13 (0.18)	0 (-)	-0.48 (-1.17, 0.21)	0.18
	Medium-intensity education	0.31 (0.28)	0.68 (0.28)	-0.10 (-0.63, 0.43)	0.72
	High-intensity education	0.58 (0.39)	0.58 (0.15)	-0.48 (-1, 0.05)	0.08
Restroom has no signs of damage	Control	0.13 (0.18)	0.20 (0.08)		

	Low-intensity education	0 (0)	0 (-)	-0.07 (-0.21, 0.07)	0.32
	Medium-intensity education	0 (0)	0.15 (0.15)	0.06 (-0.06, 0.18)	0.32
	High-intensity education	0.03 (0.07)	0.12 (0.14)	0.01 (-0.10, 0.12)	0.85
Restroom has door locks available	Control	0.58 (0.59)	0.57 (0.61)		
	Low-intensity education	0.13 (0.18)	0 (-)	0.01 (-0.01, 0.04)	0.32
	Medium-intensity education	0.19 (0.33)	0.32 (0.40)	0.18 (-0.09, 0.45)	0.19
	High-intensity education	0.33 (0.31)	0.28 (0.28)	-0.04 (-0.76, 0.69)	0.92
Soap available in restroom	Control	0.44 (0.62)	0.38 (0.53)		
	Low-intensity education	0 (0)	0 (-)	0.06 (-0.06, 0.18)	0.32
	Medium-intensity education	0.07 (0.13)	0.15 (0.25)	0.10 (-0.09, 0.29)	0.29
	High-intensity education	0.12 (0.16)	0.18 (0.23)	0.13 (-0.05, 0.30)	0.16
Lights are functional in restroom	Control	0.60 (0.38)	0.79 (0.30)		
	Low-intensity education	0.65 (0.03)	1 (-)	0.15 (0.04, 0.26)	0.01
	Medium-intensity education	0.50 (0.42)	0.63 (0.32)	-0.02 (-0.53, 0.50)	0.95
	High-intensity education	0.87 (0.16)	0.54 (0.44)	-0.51 (-1.08, 0.07)	0.08
Restroom is well-lit	Control	0.56 (0.09)	0.79 (0.30)		
	Low-intensity education	0.77 (0.15)	0 (-)	-0.89 (-1.19, -0.59)	$p < 0.01$
	Medium-intensity education	0.60 (0.47)	0.70 (0.36)	-0.11 (-0.81, 0.58)	0.75

	High-intensity education	0.88 (0.25)	0.84 (0.20)	-0.26 (-0.61, 0.09)	0.15
School principal is satisfied with restroom's sanitation**	Control	0.50 (0.71)	0.50 (0.71)		
	Low-intensity education	0.50 (0.71)	0 (-)	--	
	Medium-intensity education	0.57 (0.53)	0.40 (0.55)	0.76 (0.48, 1.21)	0.24
	High-intensity education	0.50 (0.58)	0.50 (0.71)	0.78 (0.59, 1.04)	0.09
School principal is satisfied with children's hygiene**	Control	0.50 (0.71)	0.50 (0.71)		
	Low-intensity education	1 (0)	1 (-)	0.74 (0.46, 1.21)	0.23
	Medium-intensity education	0.43 (0.53)	0.20 (0.45)	0.57 (0.49, 0.66)	p < 0.01
	High-intensity education	0.50 (0.58)	0.50 (0.71)	0.78 (0.59, 1.04)	0.09

CG = control group. CI = confidence interval. IG = intervention group. IRR = incidence-rate ratio. MOOE = maintenance and other operating expenses. SD = standard deviation. WaSH = water, sanitation, and hygiene.
The p-value refers to the difference in intervention effect between the respective IG and the CG.
*We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences in the mean changes of the desired outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the school's age, enrolment size, and MOOE budget; adjustments were based on covariates' measurements at baseline.
**We used a multilevel mixed-effects Poisson regression model to estimate intervention effects, which can be interpreted as the IRR of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, while adjusting for the school's enrolment size and clustering by city.

Table S4.7 Surveys conducted during this trial: outcomes, covariates, and sample sizes.

Survey	Outcomes	Covariates	Baseline N	Endline N
Children's HL questionnaire	Binary variables: HL overall passing score, overall knowledge about germs passing score, overall knowledge about HW passing score	age, sex, grade	729	660
	Continuous variables: HL overall score, overall knowledge about germs score, overall knowledge about HW score	same as above	same as above	same as above
Children's health examination	Binary variables: stunting, undernutrition, overnutrition, dehydration (mild, moderate, severe, any)	age, sex, grade	Height: 741; weight: 739; urine: 724.	Height: 712; weight: 710; urine: 706.
	Continuous variables: BAZ, HAZ, urine specific gravity	age, sex, grade	same as above	same as above
Children's demographic survey	Binary variables: is healthy; rarely goes to bed while feeling hungry; is satisfied with school restroom; is satisfied with school HW area.	age, sex, grade, parent's education, parent's employment, exposure to SHS, home WaSH[1], SES[2], number of adults, number of children, parent is illiterate or disabled, food security[3], school WaSH[4]	n/a	828
		Categorical/ordinal variables: source of drinking water, flooring material, type of vehicle(s) owned, common mode of transportation to school.	same as above	same as above

Children's handwashing	Binary variables: washed hands after using toilet/urinal; used correct technique; used soap; washed hands for correct duration of time	sex	268	363
	Continuous variables: HW overall score	sex	same as above	same as above
Inspection of school WaSH facilities	Binary variables: is clean, is functional, is accessible, is well-let, is not too dark, provides privacy, has no flies, has no signs of graffiti, has no signs of mould, has no signs of damage, has no bad smell, has a garbage can, has a HW basin near toilet/urinal	age of school, primary or secondary grade levels, MOOE budget, location (city)	86	87
Interview with school principals	Binary variables: has policy to clean restrooms daily, has policy to designate a staff member to ensure cleaning policy is enforced; is satisfied with children's hygiene; is satisfied with school's sanitation	n/a	11	10

BAZ = body mass index-for-age Z score. HAZ = height-for-age Z score. HL = health literacy. HW = handwashing. MOOE = maintenance and other operating expenses. SES = socioeconomic status. SHS = second-hand smoke. WaSH = water, sanitation, and hygiene.
[1]home WaSH = has restroom, shares restroom with another family, restroom is outside of house, has toilet, has HW basin, has faucet with running water.
[2]SES = has electricity, refrigerator, cell phone, computer, clock/watch, electric fan.
[3]food security = enough food, variety of food, can afford to buy food, has asked/begged for food, eats freshly cooked food more often than pre-cooked food.
[4]school WaSH = school restroom is clean; school HW area is clean.

Table S4.8 Regression models used to measure intervention effects.

Outcome	Outcome type	Model	Adjusted for (covariates/ mediators)	Random effect (intercept)	Standard errors	Stata script
overall HL score, overall germs knowledge score, overall HW knowledge score	continuous	multilevel mixed-effects linear regression	child's sex & age, parent's education, SES, outcome at baseline	city	robust	(long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mixed scorehw_ post##yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// c.scorehwpre|| city_0:, vce(robust) restore
overall HL pass, overall germs knowledge pass, overall HW knowledge pass	binary	multilevel mixed-effects logistic regression; multilevel mixed-effects Poisson regression	child's sex & age, parent's education, SES, outcome at baseline	city	robust	(long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 melogit scorehwpass_ post##yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// scorehwpasspre || city_0:, vce(robust) or restore or (long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mepoisson scorehwpass_ post##yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// scorehwpasspre || city_0:, vce(robust) irr restore
prevalence of: stunting,	binary	multilevel mixed-effects	child's sex & age, parent's	city	robust	(long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0

undernutrition, overnutrition		logistic regression	education, SES			melogit stunted_ post##yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// || city_0:, vce(robust) or restore
persistence and incidence of: stunting, undernutrition, overnutrition	binary	multilevel mixed-effects logistic regression; multilevel mixed-effects Poisson regression; exact logistic regression	child's sex & age, parent's education, SES	city	robust	(wide file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 melogit stunted_persistence i.yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// || city_0:, or vce(robust) restore (wide file) for stunted_incidence only: preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 exlogistic stunted_incidence yesiga isfemale agey_0 parenteducode ses2 restore (wide file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mepoisson sevthinandthin_persistence i.yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// c.homepplnr c.adultworkernr i.homecroutsd c.scorefs c.nowaternrsc_0 /// c.crnohwusameroomnrsc_0 || city_0:, irr vce(robust) restore (wide file) preserve drop if yesiga + yesigc !=0

						melogit sevthinandthin_persistence i.yesigbandd i.isfemale c.agey_0 c.parenteducode c.ses2 /// c.homepplnr c.adultworkernr c.scorefs i.homecroutsd c.nowaternrsc_0 /// c.crnohwusameroomnrsc_0 || city_0:, or vce(robust) restore
HAZ, BAZ, BMI	continuous	multilevel mixed-effects linear regression; differences in differences	child's sex & age, parent's education, SES	city	robust	(long file) preserve drop if yesigb + yesigc + yesigbandd!=0 mixed haz_ post##yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// || city_0:, vce(robust) diff haz_, t(yesiga) p (post) cov (isfemale agey_0 parenteducode ses2) /// report cluster (city_0) robust restore
change in HAZ, BAZ, BMI; height and weight gain	continuous	multilevel mixed-effects linear regression	child's sex & age, parent's education, SES	city	robust	(wide file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mixed dif_haz i.yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// || city_0:, vce(robust) restore (wide file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mixed heightgain i.yesiga i.isfemale c.agey_0 c.parenteducode c.ses2 /// || city_0:, vce(robust) restore
dehydration: mild, moderate, severe, any	binary	multilevel mixed-effects logistic	child's sex & age, SES	city	robust	(long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 melogit yesproteinuria_ post##yesiga i.isfemale c.agey_0 c.ses2 ///

		regression; multilevel mixed-effects Poisson regression				|| city_0:, or vce(robust) restore or preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mepoisson veryhiconcurn1030_ post##yesiga i.isfemale c.agey_0 c.ses2 /// || city_0:, irr vce(robust) restore
urine specific gravity	continuous	multilevel mixed-effects linear regression	child's sex & age, SES	city	robust	(long file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 mixed specificgravitysg_ post##yesiga i.isfemale c.agey_0 c.ses2 /// || city_0:, vce(robust) restore
observed HW practice: washed hands after using toilet/urinal, used soap, washed for correct duration of time, used correct technique	binary	multilevel mixed-effects logistic regression	female, primary school, MOOE budget, school restroom has water, HW basin-to-student ratio	city	robust	(wide file) preserve drop if yesigb + yesigc + yesigd + yesigbandd!=0 melogit washedhands_1 i.yesiga i.isfemale c.mooe_0 c.studsinkratiov2_0 /// i.yesprimary c.yeswaternrsc_0 || city:,or vce(robust) restore
observed HW practice score	continuous	multilevel mixed-	female,	city	robust	(wide file) preserve

		effects linear regression	primary school, MOOE budget, school restroom has water, HW basin-to-student ratio			drop if yesigb + yesigc + yesigd + yesigbandd!=0 mixed score2modf_1 i.yesiga i.isfemale c.mooe_0 c.studsinkratiov2_0 /// i.yesprimary c.yeswaternrsc_0 || city:, vce(robust) restore
WaSH adequacy score (of school restrooms)	continuous	multilevel mixed-effects linear regression	school's annual enrollment, age of school, MOOE budget[1]	city	robust	(long file) preserve drop if igb + igc + igd + igbandd!=0 mixed yesfliesnrsc_ post##iga c.enrollallpreo c.ageschoolpreo c.mooepreo /// || cityid:, vce(robust) restore
Satisfaction of school principals with: school's sanitation and children's hygiene	binary	Poisson regression	school's annual enrollment	n/a	clustered by city	(long file) preserve drop if igb + igc + igd + igbandd!=0 poisson yesissatisfiedstudentshygiene_ post##iga c.enrollallpreo, irr vce (cluster cityid) restore

BAZ = body mass index-for-age Z score. HAZ = height-for-age Z score. HL = health literacy. HW = handwashing. MOOE = maintenance and other operating expenses. SES = socioeconomic status. SHS = second-hand smoke. WaSH = water, sanitation, and hygiene.
[1]home WaSH = has restroom, shares restroom with another family, restroom is outside of house, has toilet, has HW basin, has faucet with running water.
[2]SES = has electricity, refrigerator, cell phone, computer, clock/watch, electric fan.
[3]food security = enough food, variety of food, can afford to buy food, has asked/begged for food, eats freshly cooked food more often than pre-cooked food.
[4]school WaSH = school restroom is clean; school HW area is clean.

Table S4.9 Expanded table: characteristics of study population by study arm.

	Control	**Low-intensity health education**	**Medium-intensity health education**	**High-intensity health education**	**Total**
Characteristics	n (%)	n (%)	n (%)	n (%)	n (%)
Individual level (N = 756)					
Male	30 (38.5)	45 (38.8)	158 (44.4)	81 (39.3)	314 (41.5)
Adolescent (age ≥ 13 years)	3 (3.9)	1 (0.9)	95 (26.7)	11 (5.3)	110 (14.6)
Household factors (N= 828)	n (%)	n (%)	n (%)	n (%)	n (%)
Demographic and caregiver's characteristics					
Number of adults in home					
0	1 (1.2)	4 (3.5)	6 (1.5)	5 (2.2)	16 (1.9)
1 to 2	27 (31.8)	45 (39.5)	128 (32.9)	74 (31.9)	279 (33.7)
3 to 4	37 (43.5)	28 (24.6)	140 (36)	70 (30.2)	277 (33.5)
5 or more	17 (20)	29 (25.4)	91 (23.4)	50 (21.6)	187 (22.6)
> 11	3 (3.5)	8 (7)	24 (6.2)	33 (14.2)	69 (8.3)
Number of children in home					
1 to 2	37 (43.5)	65 (57)	198 (50.9)	106 (45.7)	412 (49.8)
3 to 4	41 (48.2)	30 (26.3)	128 (32.9)	75 (32.3)	275 (33.2)
5 to 11	6 (7.1)	14 (12.3)	53 (13.6)	37 (15.9)	110 (13.3)
> 11	1 (1.2)	5 (4.4)	10 (2.6)	14 (6)	31 (3.7)
Highest level of education completed by parent/caregiver					
None	0	0	0	1 (0.4)	1 (0.1)
Elementary	2 (2.4)	6 (5.3)	22 (5.7)	23 (9.9)	53 (6.4)

Secondary	15 (17.6)	42 (36.8)	158 (40.6)	86 (37.1)	304 (36.7)
Vocational	0	1 (0.9)	16 (4.1)	11 (4.7)	28 (3.4)
College	68 (80)	65 (57)	193 (49.6)	111 (47.8)	442 (53.4)
Number of adults who are employed, median (IQR)	2 (2 - 3)	2 (1 - 3)	2 (1 - 3)	2 (1 - 3)	2 (0 - 8)
0	2 (2.4)	5 (4.4)	12 (3.1)	12 (5.2)	31 (3.7)
1	17 (20)	33 (28.9)	117 (30.1)	48 (20.7)	219 (26.4)
2	35 (41.2)	41 (36)	128 (32.9)	84 (36.2)	290 (35)
3 to 4	25 (29.4)	24 (21.1)	94 (24.2)	56 (24.1)	200 (24.2)
5 or more	6 (7.1)	11 (9.6)	38 (9.8)	32 (13.8)	88 (10.6)
Number of children who are employed, median (IQR)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0.5)	0 (0 - 5)
0	75 (88.2)	99 (86.8)	335 (86.1)	174 (75)	691 (83.5)
1	6 (7.1)	4 (3.5)	26 (6.7)	21 (9.1)	57 (6.9)
2	2 (2.4)	3 (2.6)	15 (3.9)	10 (4.3)	30 (3.6)
3 to 4	2 (2.4)	6 (5.3)	8 (2.1)	15 (6.5)	31 (3.7)
5 or more	0	2 (1.8)	5 (1.3)	12 (5.2)	19 (2.3)
Someone at home is a smoker	31 (36.5)	52 (45.6)	190 (48.8)	117 (50.4)	394 (47.6)
Someone smokes inside home	9 (10.6)	26 (22.8)	94 (24.2)	74 (31.9)	204 (24.6)
Parent/caregiver is person with disability	4 (4.7)	8 (7)	30 (7.7)	18 (7.8)	61 (7.4)
Parent/caregiver cannot read	0	1 (0.9)	12 (3.1)	8 (3.4)	21 (2.5)
Socioeconomic characteristics (N = 828)					
Material of home's flooring					
Cement	36 (42.4)	57 (50)	199 (51.2)	116 (50)	412 (49.8)
Ceramic	40 (47.1)	54 (47.4)	136 (35)	87 (37.5)	320 (38.6)

Sand/soil	1 (1.2)	1 (0.9)	3 (0.8)	4 (1.7)	10 (1.2)
Wood	8 (9.4)	2 (1.8)	51 (13.1)	25 (10.8)	86 (10.4)
No electricity	0	0	3 (0.8)	1 (0.4)	4 (0.5)
No cell phone	2 (2.4)	7 (6.1)	29 (7.5)	21 (9.1)	60 (7.2)
No computer	32 (37.6)	71 (62.3)	249 (64)	140 (60.3)	496 (59.9)
No watch/clock	3 (3.5)	5 (4.4)	25 (6.4)	13 (5.6)	47 (5.7)
No electric fan	0	1 (0.9)	4 (1)	4 (1.7)	9 (1.1)
No vehicle	26 (30.6)	38 (33.3)	161 (41.4)	99 (42.7)	328 (39.6)
Bicycle/pedicab only	4 (4.7)	7 (6.1)	50 (12.9)	34 (14.7)	97 (11.7)
Tricycle/scooter/motorcycle only	14 (16.5)	43 (37.7)	109 (28)	57 (24.6)	225 (27.2)
Car only	38 (44.7)	18 (15.8)	53 (13.6)	28 (12.1)	137 (16.5)
Food insecurity factors (N =828)					
Not enough food	0	1 (0.9)	13 (3.3)	13 (5.6)	27 (3.3)
Does not eat variety of food	1 (1.2)	4 (3.5)	19 (4.9)	10 (4.3)	34 (4.1)
Often cannot afford to buy food	0	4 (3.5)	17 (4.4)	8 (3.4)	29 (3.5)
Often has asked/begged for food	26 (30.6)	33 (28.9)	82 (21.1)	56 (24.1)	198 (23.9)
Eats pre-cooked food more often than freshly cooked food	11 (12.9)	13 (11.4)	36 (9.3)	20 (8.6)	82 (9.9)
WaSH-related factors (N = 828)					
Source of drinking water in home					
Faucet only	9 (10.6)	35 (30.7)	70 (18)	49 (21.1)	163 (19.7)
Filtered only	16 (18.8)	25 (21.9)	104 (26.7)	59 (25.4)	206 (24.9)
Bottled/from water refilling station only	48 (56.5)	38 (33.3)	189 (48.6)	104 (44.8)	385 (46.5)
Any bottled water	57 (67.1)	53 (46.5)	214 (55)	121 (52.2)	451 (54.5)

IQR = interquartile range. WaSH = water, sanitation, and hygiene.
Percentages were calculated from smaller denominators than those shown at the top of the table for all variables because of missing values.

Table S4.10 Expanded table: effect of intervention on children's hygiene-related health literacy and observed handwashing.

Outcome	Study arm	Baseline		Endline		Effect of intervention (95% CI)	p-value
		n	%	n	%		
Knows when to wash hands*	Control	62	79.5	78	96.3		
	Low-intensity education	99	97.6	96	97	0.92 (0.70, 1.22)	0.57
	Medium-intensity education	296	85.6	290	96.4	0.99 (0.80, 1.22)	0.90
	High-intensity education	159	77.6	169	93.9	1.05 (0.82, 1.36)	0.68
Knows how long to wash hands*	Control	26	33.3	46	56.8		
	Low-intensity education	46	40.7	83	83.8	1.13 (0.63, 2.04)	0.68
	Medium-intensity education	86	24.9	135	44.9	1.17 (0.71, 1.92)	0.53
	High-intensity education	73	35.6	111	61.7	1.06 (0.19, 5.84)	0.95
Knows how to prevent infection by washing hands*	Control	75	96.2	77	95.1		
	Low-intensity education	109	96.5	97	98	1.06 (1.00, 1.12)	0.07
	Medium-intensity education	316	91.3	285	94.7	1.10 (1.04, 1.15)	$p < 0.01$
	High-intensity education	200	97.6	174	96.7	1.03 (0.97, 1.09)	0.38
Knows that germs are disease-causing organisms*	Control	76	97.4	80	98.8		
	Low-intensity education	109	96.5	99	100	0.98 (0.95, 1.01)	0.15
	Medium-intensity education	334	96.5	296	98.3	0.99 (0.95, 1.03)	0.66
	High-intensity education	192	93.7	174	96.7	1.02 (0.96, 1.09)	0.49
Knows where germs may be found*	Control	58	74.4	78	96.3		
	Low-intensity education	90	79.7	97	98	0.83 (0.49, 1.42)	0.50
	Medium-intensity education	282	81.5	288	95.7	0.83 (0.54, 1.27)	0.39
	High-intensity education	154	75.1	165	91.7	0.87 (0.58, 1.30)	0.49

Knows that germs can be removed with soap* and water	Control	71	91	80	98.8		
	Low-intensity education	104	92	97	98	1.01 (0.98, 1.04)	0.48
	Medium-intensity education	311	89.9	293	97.3	1.06 (0.99, 1.13)	0.09
	High-intensity education	176	85.9	174	96.7	1.13 (1.07, 1.20)	p < 0.01
Knows that a restroom that is not clean may contain germs*	Control	59	75.6	62	76.5		
	Low-intensity education	111	98.2	91	91.9	0.97 (0.63, 1.50)	0.90
	Medium-intensity education	211	61	208	69.1	1.21 (0.81, 1.80)	0.36
	High-intensity education	170	82.9	156	86.7	1.09 (0.75, 1.57)	0.66
Knows to wash fruits and vegetables before eating to remove germs and prevent infection*	Control	67	85.9	70	86.4		
	Low-intensity education	107	94.7	92	92.9	1 (0.81, 1.24)	0.98
	Medium-intensity education	302	87.3	261	86.7	1.04 (0.88, 1.23)	0.67
	High-intensity education	197	96.1	165	91.7	0.97 (0.81, 1.16)	0.73
Knows how germs can be spread from person to person*	Control	62	79.5	77	95.1		
	Low-intensity education	88	77.9	98	99	1.06 (0.84, 1.33)	0.65
	Medium-intensity education	293	84.7	284	94.4	1.01 (0.85, 1.20)	0.92
	High-intensity education	161	78.5	166	92.2	1.07 (0.89, 1.28)	0.48
Knows primary symptoms of infection*	Control	74	94.9	77	95.1		
	Low-intensity education	109	96.5	97	98	1.02 (0.93, 1.12)	0.62
	Medium-intensity education	315	91	278	92.4	1.04 (0.96, 1.11)	0.35
	High-intensity education	194	94.6	173	96.1	1.01 (0.94, 1.09)	0.72
Knows secondary symptoms of infection*	Control	37	72.6	27	84.4		
	Low-intensity education	105	92.9	62	98.4	0.82 (0.81, 0.83)	p < 0.01
	Medium-intensity education	120	80	42	97.7	1.15 (1.07, 1.24)	p < 0.01
	High-intensity education	123	81.5	67	87	0.82 (0.63, 1.07)	0.14
Washed hands with soap**	Control			2	11.1		

	Low-intensity education						
	Medium-intensity education			1	6.7	1.75 (1.75, 1.75)	p < 0.01
	High-intensity education			2	5	0.46 (0.13, 1.66)	0.24
Used correct handwashing technique**	Control			8	44.4		
	Low-intensity education			1	6.7	0.10 (0.07, 0.15)	p < 0.01
	Medium-intensity education			3	20	11 (5.53, 21.7)	p < 0.01
	High-intensity education			3	7.5	0.12 (0.10, 0.15)	p < 0.01

aOR = adjusted odds ratio. CG = control group. CI = confidence interval. IG = intervention group. IRR = incidence-rate ratio. MOOE = maintenance and other operating expenses. SES = socioeconomic status.
The p-value refers to the difference in intervention effect between the respective IG and the CG.
*We used a multilevel mixed-effects Poisson regression model to estimate intervention effects, which can be interpreted as the IRR of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and desired outcome at baseline, and the parent/caregiver's education level and SES.
**We used a multilevel mixed-effects logistic regression model to estimate intervention effects expressed as the aOR of the prevalence at endline of the desired outcome between the respective IG and CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, attendance in primary school, the school's MOOE budget and handwashing basin-to-student ratio, and the availability of water in the school restroom.

Table S4.11 Expanded table: effect of intervention on children's malnutrition status.

Outcome		Study arm	Baseline		Endline		Effect of intervention (95% CI)	p-value
			n	%	n	%		
Undernutrition	**Severe thinness**	Control	4	5.1	3	3.7		
		Low-intensity education	5	4.8	3	2.9	*	
		Medium-intensity education	21	6	18	5.8	*	
		High-intensity education	7	3.4	10	5.5	*	
	Thinness	Control	2	2.6	0	0		
		Low-intensity education	3	2.9	3	2.9	*	
		Medium-intensity education	10	2.8	6	1.9	*	
		High-intensity education	6	2.9	3	1.7	*	
Overnutrition	**Overweight**	Control	25	32.1	19	23.5		
		Low-intensity education	27	26	18	17.3	0.80 (0.47, 1.36)	0.41
		Medium-intensity education	73	20.7	44	14.2	0.72 (0.39, 1.31)	0.28
		High-intensity education	44	21.4	27	14.9	0.64 (0.42, 0.98)	0.04
	Obesity	Control	2	2.6	17	21		
		Low-intensity education	5	4.8	13	12.5	0.52 (0.37, 0.72)	p < 0.01
		Medium-intensity education	3	0.9	24	7.7	0.78 (0.49, 1.23)	0.28
		High-intensity education	0	0	11	6.1	0.76 (0.59, 0.97)	0.03

aOR = adjusted odds ratio. BAZ = body mass index-for-age Z score. BMI = body mass index. CG = control group. CI = confidence interval. cm = centimetre. HAZ = height-for-age Z score. IG = intervention group. kg = kilogram.
The p-value refers to the difference in intervention effect between the respective IG and the CG. We classified nutrition status using the 2007 WHO Growth Reference. Stunting = HAZ < −2 SD. Undernutrition = composite variable comprised of thinness (−3 < BAZ < −2) and severe thinness (BAZ < −3). Overnutrition = composite variable comprised of overweight (1 < BAZ < 2) and obesity (BAZ > 2).

*No result.
**We used a multilevel mixed-effects logistic regression model to estimate intervention effects, which can be expressed as the aOR of change in prevalence of a desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child’s sex and age, and the parent/caregiver’s education level and socioeconomic status SES.

Table S4.12 Effect of the intervention on changes in children's growth indicators.

Outcome	Study arm	Endline mean (± SD)	Effect of intervention (95% CI)	p-value
Change in HAZ (stunting)	Control	-0.26 (0.67)		
	Low-intensity education	-0.02 (1.09)	0.23 (-0.04, 0.49)	0.09
	Medium-intensity education	0.05 (0.54)	0.21 (-0.13, 0.55)	0.22
	High-intensity education	-0.03 (0.45)	0.15 (-0.04, 0.34)	0.12
Change in BAZ (thinness)	Control	0.12 (0.68)		
	Low-intensity education	-0.02 (0.94)	-0.22 (-0.35, -0.09)	p < 0.01
	Medium-intensity education	0.09 (0.73)	-0.04 (-0.25, 0.17)	0.72
	High-intensity education	0.06 (0.59)	-0.05 (-0.28, 0.18)	0.68
Change in BMI	Control	0.86 (1.78)		
	Low-intensity education	0.14 (4.58)	-0.99 (-1.67, -0.31)	p < 0.01
	Medium-intensity education	0.62 (1.37)	-0.22 (-0.79, 0.35)	0.45
	High-intensity education	0.58 (1.25)	-0.21 (-0.62, 0.21)	0.33
Height (cm) gain	Control	1.52 (5.08)		
	Low-intensity education	3.65 (1.67)	2.46 (0.39, 4.53)	0.02
	Medium-intensity education	3.97 (3.92)	3.62 (1.43, 5.81)	p < 0.01
	High-intensity education	3.17 (3.28)	3.02 (1.80, 4.25)	p < 0.01
Weight (kg) gain	Control	2.84 (2.85)		
	Low-intensity education	2.90 (2.76)	0.14 (-0.39, 0.67)	0.60
	Medium-intensity education	3.37 (3.22)	0.52 (0.44, 0.59)	p < 0.01
	High-intensity education	2.85 (2.73)	0.23 (-0.49, 0.94)	0.54

BAZ = body mass index-for-age Z score. BMI = body mass index. CG = control group. CI = confidence interval. cm = centimetre. HAZ = height-for-age Z score. IG = intervention group. kg = kilogram. SD = standard deviation. SES = socioeconomic status.

The p-value refers to the difference in intervention effect between the respective IG and the CG.
*We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences in the mean changes of the desired follow-up outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex and age and the parent/caregiver's education level and SES.

Table S4.13 Expanded table: effect of intervention on children's dehydration status and urine specific gravity.

Outcome	Study arm	Baseline		Endline		Effect of intervention (95% CI)	p-value
		n	%	n	%		
Any* dehydration	Control	69	89.6	76	97.4		
	Low-intensity education	91	88.4	97	93.3	0.46 (0.04, 5.21)**	0.53
	Medium-intensity education	305	90.2	272	82.9	0.14 (0.01, 1.72)**	0.12
	High-intensity education	184	89.8	160	88.9	0.24 (0.01, 6.34)**	0.39
Urine specific gravity	Control	1.027	0.006	1.028	0.004		
	Low-intensity education	1.026	0.006	1.028	0.006	-0.000 (-0.001, 0.000)***	0.13
	Medium-intensity education	1.026	0.006	1.025	0.008	-0.004 (-0.004, -0.004)***	p < 0.01
	High-intensity education	1.026	0.006	1.026	0.007	-0.002 (-0.005, 0.002)***	0.33

aOR = adjusted odds ratio. CG = control group. CI = confidence interval. IG = intervention group. SES = socioeconomic status. U_{sg} = urine specific gravity.

The p-value refers to the difference in intervention effect between the respective IG and the CG.

*We defined any dehydration as $U_{sg} \geq 1.020$.

**We used a multilevel mixed-effects logistic regression model to estimate intervention effects, which can be expressed as the aOR of change in prevalence of a desired follow-up outcome between the respective IG and CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and SES.

***We used a multilevel mixed-effects linear regression model to estimate intervention effects, which can be interpreted as the adjusted differences in the mean changes of the desired outcome between the respective IG and the CG. The model included the respective IG, random intercept for the city, and robust standard errors. We adjusted for the child's sex, age, and SES.

Figure S4.14 CONSORT 2010 checklist for reporting a cluster-randomised controlled trial.

Section/Topic	Item No	Checklist item	Reported on page No[1]
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	1
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3
	2b	Specific objectives or hypotheses	3
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	3
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	n/a
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5, Supplementary Materials, and previously published study protocol
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5 - 6

	6b	Any changes to trial outcomes after the trial commenced, with reasons	n/a
Sample size	7a	How sample size was determined	6 and previously published study protocol
	7b	When applicable, explanation of any interim analyses and stopping guidelines	n/a
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	4 - 5
	11b	If relevant, description of the similarity of interventions	5, Supplementary Materials, and previously published study protocol
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6 - 7
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	7

Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analyzed for the primary outcome	Figure 3
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure 3
Recruitment	14a	Dates defining the periods of recruitment and follow-up	Figure 3
	14b	Why the trial ended or was stopped	n/a
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analyzed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Table 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Tables 2 - 6
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	n/a
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	10 - 11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	10
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9 - 10
Other information			
Registration	23	Registration number and name of trial registry	Abstract and 7
Protocol	24	Where the full trial protocol can be accessed, if available	7

Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	Abstract and 7

Note: In far right column, the page numbers listed correspond to the page numbers from the original manuscript. The page numbers do not correspond to the page numbers in this dissertation.

5 GENERAL DISCUSSION

Findings from the WMSP were able to address the dissertation's research questions, hypotheses, aim, and objectives. These findings, when combined with lessons learned, contribute to the growing body of evidence about school WaSH and children's environmental health.

5.1 Relationship between school WaSH and children's environmental health

School WaSH was assessed to be very inadequate in study schools. A severe shortage of WaSH facilities on school grounds was evidenced by the fact that 14 out of 15 (93%) of the study schools did not meet the guidelines for ratios for pupil-to-toilet, pupil-to-urinal, or pupil-to-HW basin. Consequently, there were long lines and long wait times to use WaSH facilities, which could have negatively impacted children's hygiene behaviours. As a result, children may have avoided using the school restroom, preferring instead to practice open urination/defecation, leave school to use the toilet at home (and possibly not return to school), and not wash their hands before eating. When WaSH facilities were present, they were observed to not be clean, not contain soap, water, or towels, and have non-functional hardware (e.g. toilets that were clogged and could not be flushed, HW basins without running water). These were additional factors that hindered children's proper and timely use of WaSH facilities.

Filipino children were at high risk of WaSH-related diseases like diarrhea. This could have been an indication that children's exposure to pathogens was not being sufficiently reduced by environmental modification or individual behavior. The finding that children were sensitive to pathogens is important to note because previous research has suggested that Filipinos could be tolerant to fecal water contamination (Moe et al. 1991)

The malnutrition profile of Filipino children present a mixed picture. On the one hand, stunting prevalence was high, which is consistent with findings from LMICs. On the other hand, overnutrition was more commonplace than undernutrition. It is possible, that with increasing globalization and higher incomes, Filipinos' dietary patterns are becoming more "westernized". In other words, increased consumption of meat and fast food, and decreased consumption of fruits and vegetables. Further exacerbating the trend toward overnutrition is the growing tendency of children to lead sedentary lifestyles. During our site visits we saw many “computer centres” located near schools where children could spend hours playing video games or using social media. Metro Manila is a megacity famous for shopping malls; the lack of nearby green and blue spaces, where one could exercise or play sports in nature, could be a barrier to children’s physical activity.

Findings from this study demonstrate the complexity of the relationship between school WaSH and children’s health. Disease transmission pathways, risk factors found outside of schools, and diverse school WaSH management strategies complicate the picture. However, it is clear that inadequate school WaSH negatively impacts children’s health and hygiene behaviors. Specifically, having too few toilets or long lines to use toilets increased children’s risks of diarrhea. Limited access to WaSH facilities harms children’s health. For example, decreased availability of HW units and no access to septic tank toilets has been associated with increased risk of diarrhea and/or vomiting (Weaver et al. 2016). While offering hygiene lessons did not reduce risk of infection, children’s avoidance of school restrooms and poor HW increased risks of diarrhea. This is a window of opportunity that highlights the need for interventions that focus on behavior change, promoting use of school restrooms and increasing HW. It is important to improve children’s perceptions of school restrooms, as perceived uncleanliness of restrooms and lack of satisfaction with restrooms increased risks of diarrhea. Thus, school WaSH intervention packages should include components such as policy, budget, and environmental modification, which creates an “enabling environment”, as well as behavioral modification.

5.2 Impacts of school WaSH intervention on health

While the intervention did not impact HAZ, it did increase height gain and decrease stunting prevalence. The intervention impacted BMI, BAZ, and weight gain, and it reduced overnutrition (overweight and obesity). However, the intervention did not impact undernutrition (thinness and severe thinness). This is consistent with findings from those of previous studies. The timing or dosing of the intervention may have masked effects on undernutrition. But a more likely reason for not detecting effects was the presence of risk factors outside of schools (e.g., in homes), as well as co-morbidities in children (e.g., diarrhoea, STH infection), which we assessed only during the cross-sectional study but not during the intervention study. We found that low-intensity HE reduced stunting and was associated with significantly lower BAZ and BMI. But more research is needed to better understand the role that HE intensity plays on malnutrition.

Medium-intensity HE reduced U_{sg}, while low-intensity HE reduced the prevalence of moderate dehydration (U_{sg} = 1.025). Greater intensity (e.g., medium- and high-intensity) of HE was required to reduce the prevalence of severe dehydration (U_{sg} = 1.030) in this population. Previous studies have reported on the positive effects of hydration on children's cognitive function. Effects range from improved short-term memory to improved performance on verbal-analogy tasks (Fadda et al. 2012). There is growing evidence about the negative effects of dehydration on children's cognitive performance (Bar-David et al. 2005), as well as on mood in college students (Zhang et al. 2019). These consequences are particularly important to protect children in LMICs from experiencing "learning poverty", or the inability to read and understand a simple text by age 10 (World Bank 2019). The situation has worsened during the COVID-19 pandemic because of school closures, which have prevented children in LMICs from accessing crucial educational resources. Projected consequences include increasing the proportion of children in LMICs who are exposed to learning poverty from 53% to 63%, as well as a loss of $10 trillion USD in future life-time earnings for an entire generation of students (World Bank 2020). This amounts to ~10% of global GDP (World Bank 2020).

5.3 Impacts of school WaSH intervention on HL and HW

The intervention did not affect overall HL, HW knowledge, or germs knowledge scores. Medium- and high-intensity HE increased children's odds of receiving a passing overall HL score (≥ 60%). The intervention, regardless of HE intensity, increased odds of receiving a passing germs knowledge score. Medium-intensity HE improved odds of knowing that HW can prevent infection, as well as common secondary symptoms of infection. High-intensity HE improved odds of knowing that HW with soap and water could remove germs from hands. In contrast, low-intensity HE reduced these odds compared to control. Previous studies have reported that poor HL is influenced by low SES and low education (Sørensen et al. 2015). Although we controlled for these covariates, it is possible that other unknown covariates influenced the relationship between intervention status and HL outcomes.

Medium- and high-intensity HE increased HW prevalence greater than control. Medium-intensity HE increased HW with soap greater and HW using the correct technique than control. But the intervention, regardless of HE intensity, was associated with lower mean HW scores measured via observation compared to control. These mixed findings confirm that changing HW practices is difficult but not impossible. A good starting point to intervene is identifying HW's facilitators and barriers. Internal facilitators include hygiene knowledge, motivations, and personal habits. External facilitators include close access to HW basins with water and soap, signage, and “nudges”. Internal barriers include lack of knowledge and lack of motivation. Some children may not have formed HW habits because no one at home taught them to do so. External barriers include lack of HW basins, lack of water and soap, and lack of reminders and nudges.

Interventions should be targeted at modifying users' behavior, context-specific, and comprehensive. Ideally an intervention package would comprise of both an empowered user-base and an enabling environment. Empowered users are individuals who have the understanding, capacities, and resources required to advocate for their own health, safety, and well-being. They can recognize deficiencies in school WaSH, identify areas for improvement, and take appropriate action. Enabling environments are schools and school personnel that work together to make it possible for the users of school WaSH to access facilities that are clean, functional, and safe. Schools need adequate WaSH infrastructure, e.g. toilets, urinals, HW basins. Policies are needed to ensure WaSH facilities are funded, operated, and maintained appropriately. School personnel are needed to provide hygiene lessons and demonstrate health-promoting behaviors. Leadership is needed to ensure that progress in school WaSH management is achieved and sustained.

5.4 Limitations

The generalizability of findings may be limited due to the lack of random sampling used during both the cross-sectional study and cRCT. During recruitment of schools, we used purposive sampling, focusing our search on schools with the largest enrolment sizes. It is possible that schools with smaller enrolment sizes had different WaSH conditions. During recruitment of children, we asked school personnel to select the class sections that would participate in our studies. School personnel may have been motivated to select top-performing class sections (known as “section one”) that were comprised of the academically gifted children. Thus, it is possible that under-performing children, often with low SES backgrounds, may have been under-represented in our study.

During the intervention study two schools were purposively assigned to the control arm. One school was an integrated school (providing education from kindergarten to grade 12) that required an admission test and gave preference to children of employees of the University of the Philippines. It is possible that children from this school had a demographic background that differed greatly from that of children from other schools. The other school had school personnel who contacted our research team and directly asked to participate on the study. It is possible that the readiness of the school personnel differed greatly from that of school personnel from other schools.

The control arm and the intervention arm were not of equal size, with the intervention arm being more than six times bigger. The intervention arm was comprised of three clusters, which had different numbers of schools and children. For example, the low-intensity HE arm had two schools, while the medium- and high-intensity HE arms had seven and four schools, respectively. The control arm had only two schools. The lack of balance across study arms may have limited the ability to make meaningful comparisons during data analysis. Having only two schools in some study arms also increased the chance of not being able to analyse some intervention effects when null data were present.

The intervention packages was centred on HE. Other components of the intervention package were unequally distributed to schools across different study arms. For example, only one school received song-writing workshops. We did not regularly assess schools’ adherence to certain parts of the intervention package, e.g. WaSH policy enforcement, provision of hygiene equipment and supplies, and repair of WaSH facilities. It is possible that adherence to these intervention components differed across study arms.

Two cross-sectional studies about water quality and children’s demographic information were not conducted at baseline but after post-intervention assessments were completed. It is possible that measurements of covariates, or the validity of the measurements, was limited by this timing. Furthermore, our ability to determine whether or not study arms were significantly different from each other at baseline was limited.

We used self-reported data to assess diarrhea. We did not corroborate findings with medical records, parents' reports, diagnostic tests, or clinical symptoms. Self-reported data may have limited reliability and validity, as children may could be biased toward reporting/not reporting because of lack of knowledge/memory, feelings of fear or embarrassment, and desires to receive attention or resources. We used urine test strips to assess hydration status via U_{sg}. Interpretation of urine test strips is semi-quantitative and relies on the investigator's ability to detect sometimes subtle color changes appearing on the urine test strips. We did not ask two investigators to independently record U_{sg}, which would have allowed us to identify and address possible discrepancies in the interpretation of results. We developed our own HL questionnaire rather than use an existing HL measurement tour. It is possible that our HL questionnaire had limited reliability for assessing HL in this population. We based observed HW prevalence rates on we saw during our unannounced visits to schools. Our physical presence in or around school restrooms and HW areas may have influenced children's HW practices.

5.5 Contributions of this research and implications

Prior to this research little was known about school WaSH and children's health in tropical megacities located in the Global South. Findings from multiple cross-sectional studies and a cRCT address this knowledge gap, contributing quantitative data about school WaSH conditions, health and nutrition outcomes, HL, and HW. We provide a blueprint for designing, implementing, and evaluating a multi-centre survey of schools with the aim of characterizing school WaSH, children's health, hygiene behaviours, and WaSH-related perceptions. We have developed a research methodology for assessing direct and indirect indicators of inadequate WaSH. Our most novel contribution was using children's dehydration, as measured by U_{sg}, to gauge water security in schools.

Furthermore this research measures the relationship between school WaSH and WaSH-related diseases. We identify elements of inadequate school WaSH (e.g. lack of water, lack of cleanliness) as risk factors of diarrhea. We measure associations between children's negative perceptions about school WaSH facilities and hygiene behaviors like toilet avoidance and poor HW. These findings provide more understanding about the complexity of managing school WaSH to promote children's health and learning, while preventing disease.

The greatest contribution is putting forth an intervention package that has reduced stunting, overnutrition, and dehydration, while improving children's HL and HW practices. Learnings from this research can be helpful for policy-makers, educators, public health practitioners, and communities of vulnerable child and adolescent users of school WaSH facilities. We identify what works best and what works least, an especially important contribution that can help with the timely prioritization of public health problems and allocation of scarce resources in similar LMIC settings.

Evidence from this research enable us to outline a concrete way forward, identifying additional knowledge gaps and possible areas for intervention, as well as implications for research, policy, and practice (Table 5.1).

Table 5.1: Implications for research, policy, and practice.

	Implications	**Rationale**
Future research	Replicate cRCT in other tropical megacities in LMICs. Consider replacing purposive sampling with random sampling.	To assess robustness and generalizability of findings.
	Compare assessment tools for measuring HL.	To assess reliability and validity.
	Compare Usg measured with urine test strips vs refractometer.	To improve reliability and validity, and assess specificity.
Policy	Recommend to the DepEd annual WaSH workshops for teachers, parents, and children.	To increase participation and engagement of stakeholders.
	Recommend to school principals to implement policy monitoring and enforcement mechanisms.	To ensure compliance with school WaSH policies.
	Recommend to school principals to designate specific personal to be responsible for cleanliness and functionality of restrooms. Recruit student restroom monitors.	To encourage ownership of school WaSH among users (school personnel and children).
Practice	Recommend to school teachers to incorporate daily hygiene reminders during classroom instruction and before critical	To reinforce lessons learned during existing HE sessions as part of school curriculum.

	times (e.g. before meals, after using toilet).	
	Encourage group HW before meal times.	To use positive peer pressure to promote hygiene behavior.
	Install low-cost, attention-grabbing “nudges” at critical locations around school to promote HW.	To promote behavior change and formation of healthy hygiene habits.

6 CONCLUSION AND OUTLOOK

This research confirms that managing school WaSH is a complex and urgent task, especially in vulnerable populations of urban poor children living in tropical megacities in LMICs. Thus, a magic-bullet solution, a one-size-fits-all approach to addressing inadequate school WaSH, although attractive in the short-term, would neither be plausible, appropriate, ethical, nor effective. Drivers of school WaSH management are empowered users and enabling environments. Harmony between these two drivers is the goal of all intervention programs. Harmony facilities communication, mutual respect and care, and goal-oriented collaboration, even in the lost high-need, low-resource settings.

The empowerment of users is an important first step. Giving children the knowledge to understand WaSH and its effects on health enhances their HL, increases their motivation to change, and builds their capacity as change agents. With this knowledge, they become better equipped to deal with future challenges, especially to environmental threats to their health and safety. It is important to make children aware that better WaSH conditions exist and that they are entitled to them. This can help to change their attitudes, making them more comfortable to report problems and expect and demand improvements.

Creating and maintaining enabling environments in schools is crucial for helping children and educators reach their full potential and meeting the demands of their respective roles in society. Schools should promote well-being through education, safety, and security. But in precarious settings, such as those in LMICs, schools may actually be making children sick. This happens when pathogens in the school environment are allowed to spread and negatively impact physical, mental, and cognitive health. Urgent action is needed to better protect children from diseases in schools. Comprehensive action is needed--not only based on educating children, but on enforcing policy, providing hygiene equipment and supplies, and maintaining clean and functional WaSH facilities. It would be futile to teach children to wash their hands if the schools they attended had no HW basins, water, or soap. Although they would learn the theory behind HW, they would not be able to practice HW.

Interventions that take into consideration the drivers of WaSH management, empowered users and enabling environments, may be poised to replace existing, single-target or single-component strategies. Comprehensive interventions require more time and resources to design and implement. Their effectiveness is more challenging to assess and quantify. Findings from our study, in line with those of previous studies (Erismann et al. 2017; Chard et al. 2019), indicate that effectiveness may be a mixed picture or even masked because multiple outcomes are being measured simultaneously. Yet comprehensive interventions should not be ignored.

7 REFERENCES

Adair LS, Fall CHD, Osmond C, et al (2013) Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. Lancet Lond Engl 382:525–534. https://doi.org/10.1016/S0140-6736(13)60103-8

Adolf E (1947) Heat exchanges, sweat formation, and water turnover. In: Physiology of man in the desert. Interscience Publishers, New York: 33-43.

Ahmed MdS, Yunus FM (2020) Trend of COVID-19 spreads and status of household handwashing practice and its determinants in Bangladesh – situation analysis using national representative data. Int J Environ Health Res 1–9. https://doi.org/10.1080/09603123.2020.1817343

Apanga PA, Kamal Lettor IB, Akunvane R (2020) Practice of COVID-19 Preventive Measures and Its Associated Factors among Students in Ghana. Am J Trop Med Hyg. 2020 Dec 7;104(2):526-531. doi: 10.4269/ajtmh.20-1301. PMID: 33289471; PMCID: PMC7866337.

Aunger R, Curtis V (2016) Behaviour Centred Design: towards an applied science of behaviour change. Health Psychol Rev 10:425–446. https://doi.org/10.1080/17437199.2016.1219673

Bar-David Y, Urkin J, Kozminsky E (2005) The effect of voluntary dehydration on cognitive functions of elementary school children. Acta Paediatr Oslo Nor 1992 94:1667–73. https://doi.org/10.1080/08035250500254670

Beale S, Johnson AM, Zambon M, et al (2021) Hand hygiene practices and the risk of human Coronavirus infections in a UK community cohort

Black RE, Victora CG, Walker SP, et al (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet Lond Engl 382:427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Buxton H, Dimaisip-Nabuab J, Duijster D, et al (2019) The impact of an operation and management intervention on toilet usability in schools in the Philippines: a cluster randomised controlled trial. BMC Public Health 19:1680. https://doi.org/10.1186/s12889-019-7833-7

Chard AN, Garn JV, Chang HH, et al (2019) Impact of a school-based water, sanitation, and hygiene intervention on school absence, diarrhea, respiratory infection, and soil-transmitted helminths: results from the WASH HELPS cluster-randomized trial. J Glob Health 9:020402. https://doi.org/10.7189/jogh.09.020402

Duijster D, Monse B, Dimaisip-Nabuab, J, et al (2017) “Fit for school” - a school-based water, sanitation and hygiene programme to improve child health: Results from a longitudinal study in Cambodia, Indonesia and Lao PDR. BMC Public Health 17:. https://doi.org/10.1186/s12889-017-4203-1

de Oliveira KHD, de Almeida GM, Gubert MB, et al (2020) Household food insecurity and early childhood development: Systematic review and meta-analysis. Matern Child Nutr 16:e12967. https://doi.org/10.1111/mcn.12967

Development Initiatives Poverty Research (2020) Inequalities in the global burden of malnutrition. https://globalnutritionreport.org/reports/2020-global-nutrition-report/inequalities-global-burden-malnutrition/ Accessed 13 February 2023

Dreibelbis R, Kroeger A, Hossain K, et al (2016) Behavior change without behavior change communication: Nudging handwashing among primary school students in Bangladesh. Int J Environ Res Public Health 13:129. https://doi.org/10.3390/ijerph13010129

Erismann S, Diagbouga S, Schindler C, et al (2017) School children's intestinal parasite and nutritional status one year after complementary school garden, nutrition, water, sanitation, and hygiene interventions in Burkina Faso. Am J Trop Med Hyg 97:904–913. https://doi.org/10.4269/ajtmh.16-0964

Fadda R, Rapinett G, Grathwohl D, et al (2012) Effects of drinking supplementary water at school on cognitive performance in children. Appetite 59:730–737. https://doi.org/10.1016/j.appet.2012.07.005

FAO (ed) (2013) Food systems for better nutrition. https://www.fao.org/3/i3301e/i3301e.pdf. Accessed 13 February 2013. FAO, Rome

FAO, IFAD, UNICEF, WFP, & WHO (2021) The state of food security and nutrition in the world 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. In: www.fao.org. https://www.fao.org/documents/card/en/c/cb4474en. Accessed 2 Aug 2021

Freeman MC, Stocks ME, Cumming O, et al (2014) Hygiene and health: systematic review of handwashing practices worldwide and update of health effects. Trop Med Int Health 19:906–916. https://doi.org/10.1111/tmi.12339

Galler JR, Bryce C, Waber DP, et al (2012) Socioeconomic outcomes in adults malnourished in the first year of life: A 40-year study. Pediatrics 130:e1–e7. https://doi.org/10.1542/peds.2012-0073

GBD 2016 Causes of Death Collaborators (2017) Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016 - The Lancet. The Lancet 390:

GBD 2016 Diarrhoeal Disease Collaborators (2018) Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the Global Burden of Disease Study 2016 - The Lancet

Infectious Diseases. https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(18)30362-1/fulltext. Accessed 30 Jul 2021

Grandjean AC (2005) Water requirements, impinging factors, and recommended intakes (in: Nutrients in drinking water, WHO, 2005)

Green JA, Mor MK, Shields AM, et al (2013) Associations of health literacy with dialysis adherence and health resource utilization in patients receiving maintenance hemodialysis. Am J Kidney Dis Off J Natl Kidney Found 62:73–80. https://doi.org/10.1053/j.ajkd.2012.12.014

Grover E, Hossain MK, Uddin S, et al (2018) Comparing the behavioural impact of a nudge-based handwashing intervention to high-intensity hygiene education: a cluster-randomised trial in rural Bangladesh. Trop Med Int Health 23:10–25. https://doi.org/10.1111/tmi.12999

Hasan MdZ, Mehdi GG, De Broucker G, et al (2021) The economic burden of diarrhea in children under 5 years in Bangladesh. Int J Infect Dis 107:37–46. https://doi.org/10.1016/j.ijid.2021.04.038

Hürlimann E, Silué KD, Zouzou F, et al (2018) Effect of an integrated intervention package of preventive chemotherapy, community-led total sanitation and health education on the prevalence of helminth and intestinal protozoa infections in Côte d'Ivoire. Parasit Vectors 11:115. https://doi.org/10.1186/s13071-018-2642-x

Ibrahim MK, Zambruni M, Melby CL, Melby PC (2017) Impact of Childhood Malnutrition on Host Defense and Infection. Clin Microbiol Rev. 2017 Oct;30(4):919-971. doi: 10.1128/CMR.00119-16. PMID: 28768707; PMCID: PMC5608884.

Institute of Medicine (US) Committee on Health Literacy (2004) Health Literacy: A Prescription to End Confusion. Nielsen-Bohlman L, Panzer AM, Kindig DA, editors. Washington (DC): National Academies Press (US). PMID: 25009856.

Jin H, Wang B, Fang Z, et al (2011) Hospital-based study of the economic burden associated with rotavirus diarrhea in eastern China. Vaccine 29:7801–7806. https://doi.org/10.1016/j.vaccine.2011.07.104

Kim S (2007) Preventable hospitalizations of dehydration: implications of inadequate primary health care in the United States. Ann Epidemiol - ANN EPIDEMIOL 17:736–736. https://doi.org/10.1016/j.annepidem.2007.07.043

Kim, YM, Choi MJ (2010) The effect of handwashing education program on knowledge, attitude and practice of handwashing in late school-aged children. J Korean Soc Sch Health 23:162–171

Lacey J, Corbett J, Forni L, et al (2019) A multidisciplinary consensus on dehydration: definitions, diagnostic methods and clinical implications. Ann Med 51:232–251. https://doi.org/10.1080/07853890.2019.1628352

Liu J, Raine A, Venables PH, et al (2003) Malnutrition at age 3 years and lower cognitive ability at age 11 Years: independence from psychosocial adversity. Arch Pediatr Adolesc Med 157:593. https://doi.org/10.1001/archpedi.157.6.593

Lundblad B, Hellström A-L (2005) Perceptions of school toilets as a cause for irregular toilet habits among schoolchildren aged 6 to 16 years. J Sch Health 75:125–128. https://doi.org/10.1111/j.1746-1561.2005.00009.x

Mahmoodabad SSM, Barkhordari A, Nabizadeh M, Ayatollahi J (2008) The effect of health education on knowledge, attitude and practice (KAP) of high school students towards Brucellosis in Yazd. World Applied Sci J 5 (4): 522-524. https://www.idosi.org/wasj/wasj5(4)/20.pdf

Mintz E, Ou J, Bowen A, et al (2007) A cluster-randomized controlled trial evaluating the effect of a handwashing-promotion program in Chinese primary schools. Am J Trop Med Hyg 76:1166–1173. https://doi.org/10.4269/ajtmh.2007.76.1166

Moe CL, Sobsey MD, Samsa GP, Mesolo V (1991) Bacterial indicators of risk of diarrhoeal disease from drinking-water in the Philippines. Bull World Health Organ 69:305–317

Monse B, Benzian H, Naliponguit E, et al (2013) The Fit for School health outcome study - a longitudinal survey to assess health impacts of an integrated school health programme in the Philippines. BMC Public Health 13:256. https://doi.org/10.1186/1471-2458-13-256

Nagaraj C, Konapur KS (2016) Effect of health education on awareness and practices related to menstruation among rural adolescent school girls in Bengaluru, Karnataka. Int J Prev PUBLIC Health Sci 2:18–21. https://doi.org/10.17354/ijpphs/2016/21

Pagán JA, Brown CJ, Asch DA, et al (2012) Health literacy and breast cancer screening among Mexican American women in South Texas. J Cancer Educ Off J Am Assoc Cancer Educ 27:132–137. https://doi.org/10.1007/s13187-011-0239-6

Philippines Department of Education (2016) Policy and guidelines for the comprehensive water, sanitation and hygiene in schools (WINS) program. https://www.deped.gov.ph/wp-content/uploads/2016/02/DO_s2016_10-1.pdf. Accessed 13 February 2023

Sørensen K, Pelikan JM, Röthlin F, et al (2015) Health literacy in Europe: comparative results of the European health literacy survey (HLS-EU). Eur J Public Health 25:1053–1058. https://doi.org/10.1093/eurpub/ckv043

Talaat M, Afifi S, Dueger E, et al (2011) Effects of Hand Hygiene Campaigns on Incidence of Laboratory-confirmed Influenza and Absenteeism in Schoolchildren, Cairo, Egypt. Emerg Infect Dis 17:619–25. https://doi.org/10.3201/eid1704.101353

Trinies V, Garn JV, Chang HH, Freeman MC (2016) The impact of a school-based water, sanitation, and hygiene program on absenteeism, diarrhea, and respiratory infection:

A matched–control trial in Mali. Am J Trop Med Hyg 94:1418–1425. https://doi.org/10.4269/ajtmh.15-0757

UN (2010) The human right to water and sanitation. Resolution adopted by the General Assembly on 28 July 2010. https://digitallibrary.un.org/record/687002?ln=fr. Accessed 13 February 2023

UN (2015) The human rights to safe drinking water and sanitation. Resolution adopted by the General Assembly on 17 December 2015. https://digitallibrary.un.org/record/821067. Accessed 13 February 2023

UN-Water (undated) Human Rights to Water and Sanitation (webpage). https://www.unwater.org/water-facts/human-rights/. Accessed 13 February 2023

UN (2017) Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202022%20refinement_Eng.pdf. Accessed 13 February 2023

Waber DP, Bryce CP, Girard JM, et al (2014) Impaired IQ and academic skills in adults who experienced moderate to severe infantile malnutrition: A 40-year study. Nutr Neurosci 17:58–64. https://doi.org/10.1179/1476830513Y.0000000061

Waber DP, Bryce CP, Girard JM, et al (2018) Parental history of moderate to severe infantile malnutrition is associated with cognitive deficits in their adult offspring. Nutr Neurosci 21:195–201. https://doi.org/10.1080/1028415X.2016.1258379

Wagner EG, Lanoix JN (1958) Excreta disposal for rural areas and small communities. Monogr Ser World Health Organ 39:1–182

Wang C, Lang J, Xuan L, et al (2017) The effect of health literacy and self-management efficacy on the health-related quality of life of hypertensive patients in a western rural area of China: a cross-sectional study. Int J Equity Health 16:58. https://doi.org/10.1186/s12939-017-0551-9

Weaver ERN, Agius PA, Veale H, et al (2016) Water, sanitation, and hygiene facilities and hygiene practices associated with diarrhea and vomiting in monastic schools, Myanmar. Am J Trop Med Hyg 95:278–287. https://doi.org/10.4269/ajtmh.15-0290

White S, Thorseth AH, Dreibelbis R, Curtis V (2020) The determinants of handwashing behaviour in domestic settings: An integrative systematic review. Int J Hyg Environ Health 227:113512. https://doi.org/10.1016/j.ijheh.2020.113512

WHO (2015) Stunting in a nutshell. https://www.who.int/news/item/19-11-2015-stunting-in-a-nutshell. Accessed 13 February 2023

WHO (2017a) Diarrhoeal disease. https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease. Accessed 30 Jul 2021

WHO (2017b) The double burden of malnutrition: policy brief. https://www.who.int/publications/i/item/WHO-NMH-NHD-17.3. Accessed 13 February 2023

WHO (undated) Growth reference data for 5-19 years: BMI-for-age. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age. Accessed 7 Feb 2023

WHO/UNICEF (2021) WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) - Progress on household drinking water, sanitation and hygiene 2000 - 2020. In: UN-Water. https://www.unwater.org/publications/who-unicef-joint-monitoring-program-for-water-supply-sanitation-and-hygiene-jmp-progress-on-household-drinking-water-sanitation-and-hygiene-2000-2020/. Accessed 19 Jul 2021

World Bank (2019) Ending Learning Poverty: What Will It Take? https://openknowledge.worldbank.org/handle/10986/32553. Accessed 13 February 2023

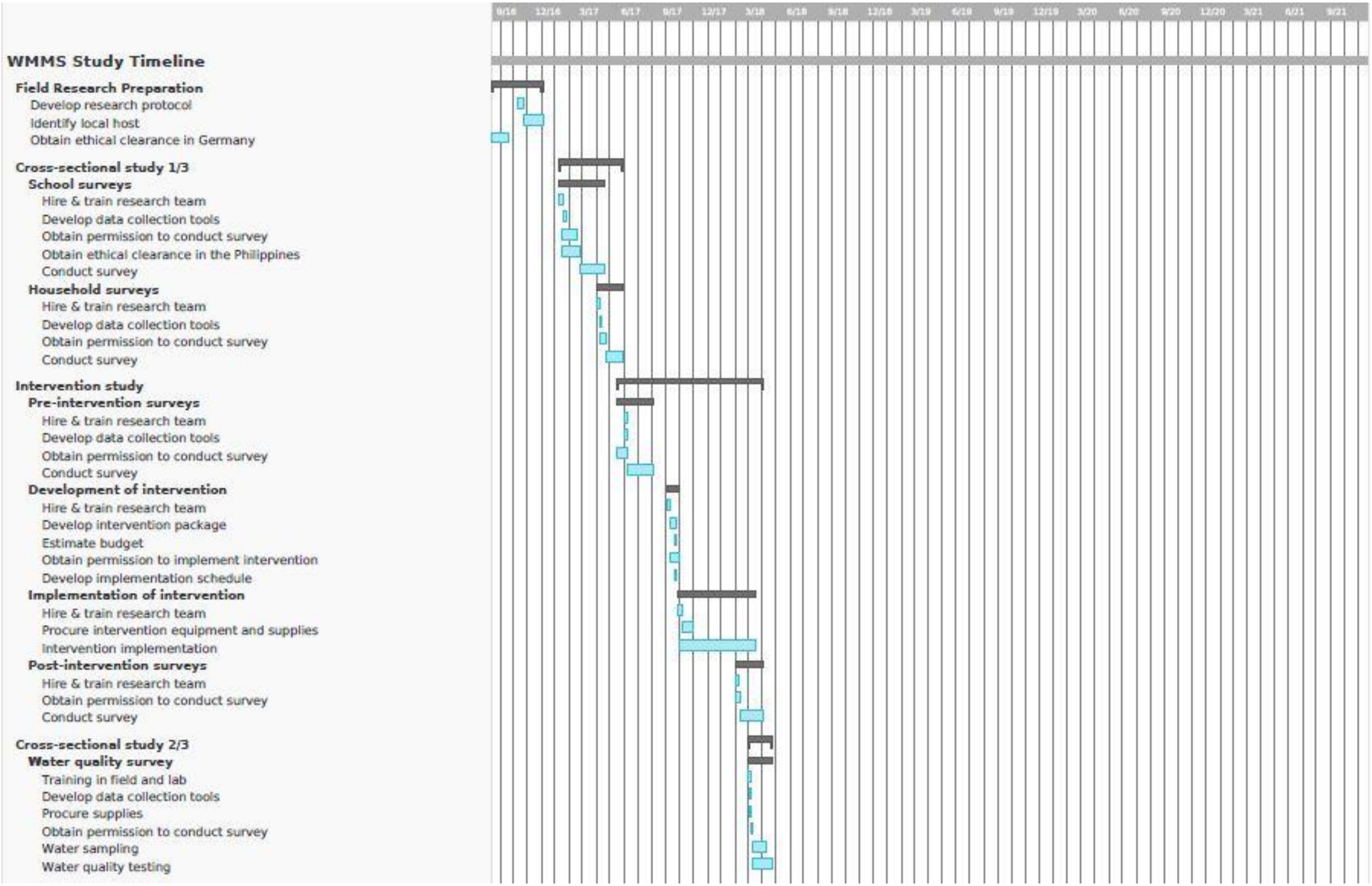
World Bank (2020) Realizing the Future of Learning: From Learning Poverty to Learning for Everyone, Everywhere. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/250981606928190510/realizing-the-future-of-learning-from-learning-poverty-to-learning-for-everyone-everywhere. Accessed 13 February 2023

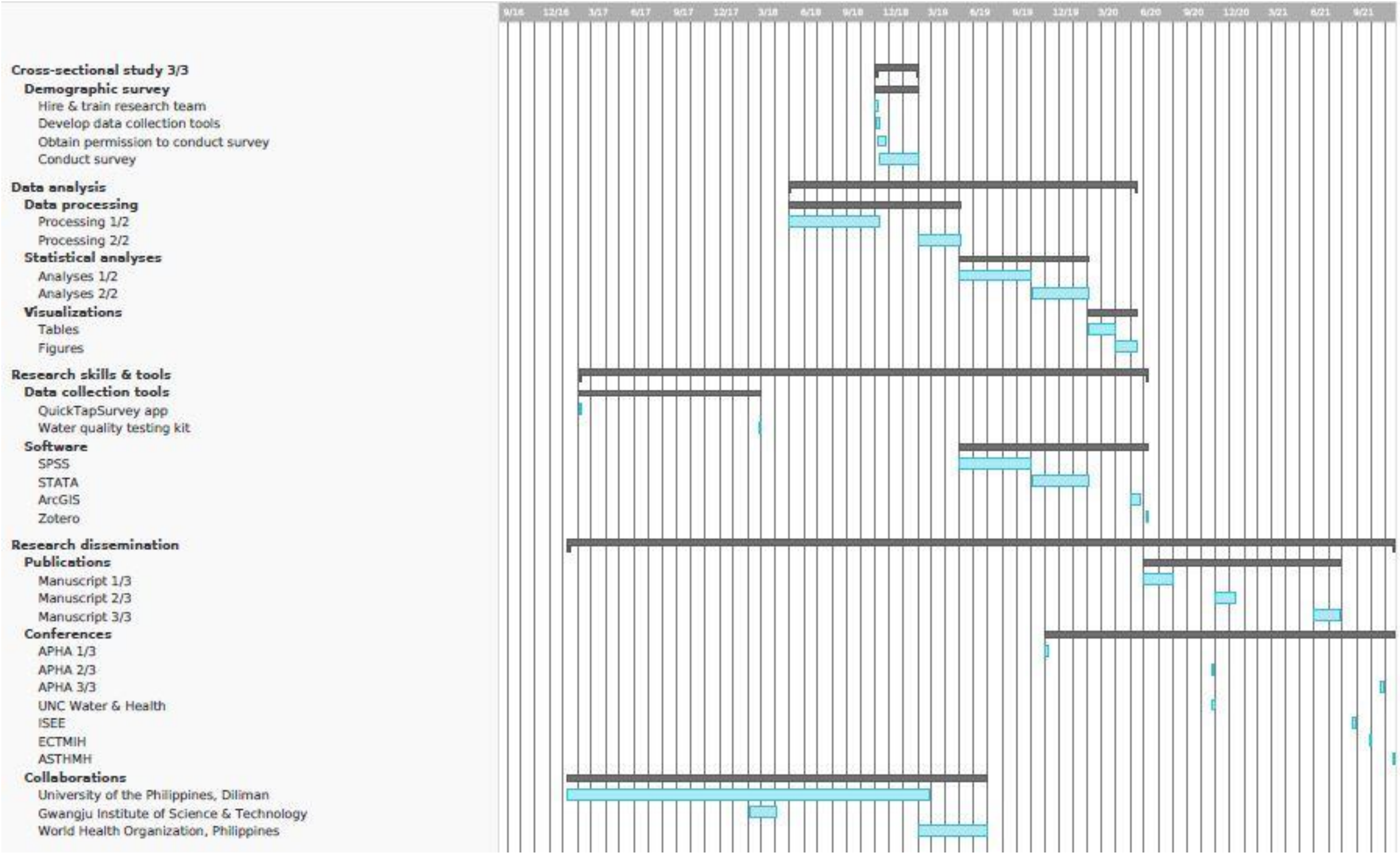
Yamaguchi S, Ojio Y, Foo JC, et al (2020) A quasi-cluster randomized controlled trial of a classroom-based mental health literacy educational intervention to promote knowledge and help-seeking/helping behavior in adolescents. J Adolesc 82:58–66. https://doi.org/10.1016/j.adolescence.2020.05.002

Zhang N, Du SM, Zhang JF, Ma GS (2019) Effects of dehydration and rehydration on cognitive performance and mood among male college students in Cangzhou, China: A self-controlled trial. Int J Environ Res Public Health 16:1891. https://doi.org/10.3390/ijerph16111891

8 APPENDICES

Appendix 8.1: WMMS Study timeline




9/16
12/16
3/17
6/17
9/17
12/17
3/18
6/18
9/18
12/18
3/19
6/19
9/19
12/19
3/20
6/20
9/20
12/20
3/21
6/21
9/21
Cross-sectional study 3/3
Demographic survey
Hire & train research team
Develop data collection tools
Obtain permission to conduct survey
Conduct survey
Data analysis
Data processing
Processing 1/2
Processing 2/2
Statistical analyses
Analyses 1/2
Analyses 2/2
Visualizations
Tables
Figures
Research skills & tools
Data collection tools
QuickTapSurvey app
Water quality testing kit
Software
SPSS
STATA
ArcGIS
Zotero
Research dissemination
Publications
Manuscript 1/3
Manuscript 2/3
Manuscript 3/3
Conferences
APHA 1/3
APHA 2/3
APHA 3/3
UNC Water & Health
ISEE
ECTMIH
ASTHMH
Collaborations
University of the Philippines, Diliman
Gwangju Institute of Science & Technology
World Health Organization, Philippines

Appendix 8.2: Research Team profile.

ID number	Sex	College degree/profession
1	F	Geography
2	F	Political Science, Pre-Law
3	M	Economics
4	M	Business Administration
5	F	Education
6	F	Mathematics
7	F	Social Science
8	F	Chemistry, Pre-Medicine
9	M	Chemistry
10	F	Mass Communications
11	F	Education
12	F	Social Science
13	M	Public Administration
14	F	Library Science
15	F	Library Science
16	F	Environmental Science
17	F	Environmental Science
18	F	Geography
19	M	Geography
20	F	Geography
21	M	Engineering
22	M	Engineering
23	M	Business Administration
24	M	Public Administration
25	F	Sociology
26	M	Sociology
27	M	Geography
28	M	Engineering
29	F	Physics
30	F	Social Science
31	M	Mass Communications
32	F	Social Science
33	F	Sociology
34	F	Development Science
35	F	Biology
36	F	Psychology
37	F	Nutrition Science
38	F	International Affairs
39	M	Mass Communications

All individuals were citizens of the Philippines and employed as college students or recent college graduates.

Appendix 8.3: Photographs of field research locations, data collection and specimen handling procedures, and school WaSH intervention activities.

8.3.1 Study area - neighborhoods, schools, and homes where we conducted surveys and implemented the WaSH intervention.

Please see attached file for photos.

a) City of Manila. b) Secondary school, Quezon City. c), g), j) Primary schools, Navotas. d), e) Primary schools, Quezon City. f) Primary school, Manila. h), i) Secondary school, Navotas. k), l) Neighborhoods in Navotas.

8.3.2 Data collection activities and handling of specimens.

Please see attached file for photos.

a) - e) Students completing questionnaire. f) Measuring height. g), h) Performing spot-check urinalysis. i), j) Preparing water specimens for assessment of coliform and E.coli contamination.

8.3.3 School WaSH intervention activities.

Please see attached file for photos.

a) - c) Health education sessions. d) Health education materials. e) Handwashing demonstration. f) Handwashing practice. g) Song-writing workshop for students. h) Distribution of health education materials. i), j) Construction of handwashing unit using a combination of new and repurposed materials. k), l) School restroom cleaning competition for students. m), n) Hygiene promotion workshop for students' parents. o), p) Soap-making workshop for students' parents. q) Handmade soap. r) Handmade hand sanitizer gel. s), t) Workshop for teachers about ceramic drinking water dispensers. u), v) WaSH policy promotion workshop for teachers.

ACKNOWLEDGEMENT

We gratefully acknowledge all members of the WaSH in Metro Manila Schools project team, study participants and their parents/guardians, school superintendents, school principals, teachers, secretaries, maintenance, security, front gate, and canteen personnel. For institutional support, the authors thank: Guenther Manske, Maike Retat-Amin, Max Voigt, Anne Grimminger, and Anna Yuen from the Doctoral Program of the ZEF, University of Bonn; Sabine Aengenendt-Baer from the ZEFc Secretariat; Alma van der Veen from the ZEF Public Relations Department; Lemnuel V. Aragones, Melanie Bantongbakal, Raian Lapresca, Mark Edward Jolejole, Paul Ezekiel Iosaria, Faye Denna, and Mikhael Cosep from the Institute of Environmental Science and Meteorology (IESM), University of the Philippines Diliman. We thank Kyoung-Woong Kim and Young-Gwang Kim from the Gwangju Institute of Science and Technology (GIST). We thank the Manila Water Company Inc. for providing technical guidance regarding water sampling. We thank Mr. Christoph Hoeser from the Institute for Hygiene and Public Health (IHPH), University of Bonn, for providing technical Geographic Information System (GIS) support and helpful advice about cartography. We thank Andrey Egorov from the United States Environmental Protection Agency (EPA) for his technical guidance regarding school-based WaSH surveys. We thank our team of field research assistants for their invaluable contributions: Jessie Bunao, Claire Olaivar, Paula Miclat, Genes Maylem, Erina Molia, Erika Macapagal, Guadalupe Diaz, Anton Valdellon, Patrick Tuano, Christian Ebonite, Cheyenne Sastrillas, Aira Galaroza, Mark Ramos, Malou Cumagon, and Janine Liao.

BOOK COVER ABSTRACT

Millions of children are exposed to inadequate water, sanitation, and hygiene (WaSH) in schools globally. Diarrhoea is a leading cause of disease, while dehydration impairs cognitive performance and malnutrition hinders physical growth. To determine the most effective school WaSH interventions, the WaSH in Metro Manila Schools (WMMS) study assessed the association between WaSH and children's health in a cross-sectional study of 15 schools, and evaluated an intervention, developed by the author, through a cluster-randomised controlled trial. The intervention consisted of policy recommendations, health and hygiene education, WASH hardware, and "software". Health education was found to reduce the prevalence of stunting, overnutrition, and severe dehydration, and to improve children's handwashing behaviour.