Handwashing Skills, Hand Bacteria Reduction, and Nutritional Status of Elementary School Children in an Urban Slum of Indonesia

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Abstract

Currently, Indonesia is a developing country with awareness and involvement in a community-based total sanitation program. One pillar of this program is handwashing practice as a prevention from an infectious disease, since many studies revealed a lack of handwashing behavior leads to bacterial contamination from hands. School children are the most vulnerable to bacterial contamination which can lead to nutritional problems. On the other hand, over population and poor-infrastructure also contribute to a lack of sanitation and personal hygiene, and these play important roles in child behavior. Therefore, this study aims to analyze handwashing skills among school children based on World Health Organization (WHO) guidelines regarding hand bacteria reduction and child nutritional status in an urban slum of Indonesia. We conducted a cross-sectional study on elementary school children in the urban slum of Bandung. Participants were the 6th grade children (11 to 14 years old). Forty-one children (24 boys and 17 girls) participated in this study. Our measures were: 1) handwashing skill observation using a checklist, 2) hand bacteria assessment before and after handwashing using a swab, and 3) child anthropometry (height and weight measurement). The association among handwashing skill, handwashing's total time duration, and bacterial assessment were analyzed using Spearman's rank correlation tests, comparison between hand bacteria before and after handwashing, and between handwashing skill and child nutritional status were studied using paired t-tests and t-test, respectively. Results showed that handwashing reduced the *E. coli* count by 0.70 log CFU/hand. Allocating time specifically to pouring water before lathering significantly lowered *E. coli* count after handwashing. Moreover, neglecting hand drying was identified as a potential factor that caused hand contamination and lowered child nutritional status.

Keywords: child handwashing skill, E. coli, pouring water, drying hands, child nutritional status

Introduction

Child mortality rates due to malnutrition are approximately 860,000 children per year and of those cases 50% feature unsafe water, inadequate sanitation, or insufficient hygiene as a cause of death (Prüss-Ustün et al. 2008). Having insufficient sanitation facilities with poor hygiene behavior will likely result in diarrhea and other related illnesses. In other words, sanitation and hygiene are inseparable in terms of their impact on human health (Cairncross et al. 2010). Even where sanitation facilities are accessible, bacterial contamination on children's hands occurs when handwashing practices are neglected (Greene et al. 2012). Therefore, the Sustainable Development Goals (SDGs) set Water Sanitation and Hygiene (WASH) as a key driver of progress on many SDGs, especially

child health and nutrition (IFPRI 2016).

Handwashing is one of ways to lower the risk of diarrhea and acute respiratory infection (Rabie and Curtis 2006; Luby et al. 2010). Unfortunately, only 19% of all people worldwide practice handwashing after contact with feces (Freeman et al. 2014). It was estimated that 297,000 deaths from diseases could be prevented by the promotion of hand hygiene (Prüss-Ustün et al. 2014). Recent studies have found that adult handwashing skill and duration relates to total bacteria reduction (Lucet et al. 2002; Jensen et al. 2015). However, there are limited studies of this nature conducted in children which investigate potential contamination processes in the context of actual living conditions (Pickering et al. 2010). Our latest study revealed that inadequate handwashing skills among children was a contributing factor towards impaired growth (Otsuka et al. 2018b).

Indonesia is one of developing countries dealing with water, sanitation, hygiene, and malnutrition problems (NIHRD 2013). Recently, urbanization has led to a proliferation of slum areas which suffer from insufficient sanitation infrastructure and poor access to clean water, bringing challenges to the practice of good hygiene behavior (Tarigan et al. 2015). It was shown by the National Survey from Indonesian Ministry of Health (NIHRD 2013) that proper handwashing rates at critical times in Indonesia only reached 47% even though handwashing facilities were found to cover more than 90% of the population. School is a crucial institution for encouraging the development of healthy and hygienic behaviors using the bottom-up approach, through children (UNICEF 2012). Therefore, having insufficient sanitation and hygiene infrastructure at school can lead to a failure in the wider development of good hygiene practices and behaviors.

This study aimed to evaluate elementary school children's awareness of handwashing skills based on WHO hand hygiene guidelines and their effectiveness in reducing total hand bacteria. We also aimed to analyze the relationship between handwashing skills and child nutritional status in an urban slum of Indonesia.

1. Method

1.1. Study area

The study area was selected purposively as one of the urban slum areas in Bandung city. Bandung city is the capital of West Java, Indonesia, with a total population of 2,490,622 registered residents (Badan Pusat Statistik Kota Bandung [BPS-Statistics of Bandung Municipality] 2017). We selected Bandung city because Bandung is currently facing issues related to environment and health. Bandung has challenges as a result from spatial and urban development. This is presenting problems including the proliferation of slum areas which suffer from limited sanitation, poor drinking water, inadequate solid waste management, and a lack of access to clean water (Tarigan et al. 2015). Kiaracondong, as the 3rd highest populated district area (*Kecamatan*) in Bandung city with total population of 132,135 (Badan Pusat Statistik Kota Bandung 2017), was selected as the study area. This area has one elementary school located within the slums, with improper sanitation facilities and handwashing station; this became the research site. Detailed information on this research location are provided elsewhere (Otsuka et al. 2018a). The location of Kiaracondong, Bandung City, is indicated in Figure 1.

1.2. Study design and participants

This study collected data on children's handwashing skills, total hand bacteria (before and after handwashing) and child anthropometry (weight and height). This was a cross-sectional study with a purposive sampling method. Participants were elementary school children in the 6th grade, ranging from 11 to 14 years of age. The 6th grade students in elementary schools were selected because of their ability to follow the study procedure. A total of 41 elementary school children (24 boys and 17 girls) took part in this study. Their handwashing skills were observed

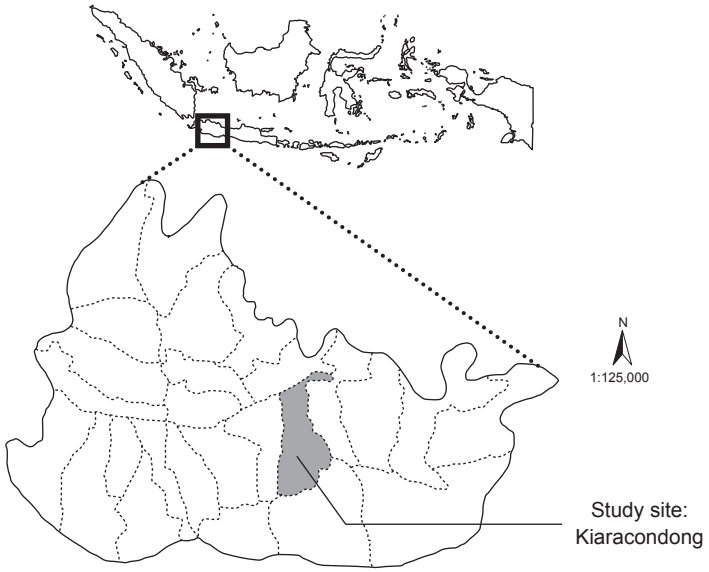

Figure 1. Study site location, Kiaracondong, Bandung, Indonesia.

using a checklist modified from WHO guidelines on handwashing for healthcare. Socio-economic status was ascertained through household monthly income and the total number of family members living in the household. The information of the school handwashing facility was also collected as supplementary data.

1.3. Procedure and measurements

Handwashing skill

Children were asked to perform their daily handwashing practice. All materials such as tap water, a water bucket with scoop, bar soap, liquid soap, and paper towels were provided by the researchers. The outer side of the liquid soap container and the bar of soap, as well as the inside of the bucket and scoop, were cleaned with water before performing handwashing but were not sterilized. We did not control either water temperature or water quality for handwashing and consider those as real conditions of the participants' living environment. The handwashing checklist was based on a modification of the hand hygiene guidelines for health care from the WHO (Figure 2), as explained elsewhere (WHO 2009). We used the checklist for every step followed by children in their handwashing behavior and used this to provide a score (maximum of 10). The time duration (1st step, 3rd-8th step, and 9th step) for handwashing was measured using a stopwatch.

Total bacteria measurements

Hand bacteria were collected before and after handwashing using a wiping kit which contained a cotton swab and 10 mL of sterile phosphate buffered saline (PBS) in a test tube (Swab test ST-25PBS; Elmex, Japan). Before children demonstrated their handwashing skill, a cotton swab moistened with sterile PBS was rolled on the surface of the dominant hand of each child (i.e., palm, backside, and fingers). All samples were kept on ice and transported to a field laboratory within 4 hours after sampling. Total bacteria analysis was conducted at the Research Unit for Clean Technology (Loka Penelitian Teknologi Bersih: LPTB), the Indonesian Institute of Science (Lembaga Ilmu Pengetahuan Indonesia: LIPI), Bandung. Samples were processed in the laboratory by membrane filtration to detect *E. coli*. Under aseptic conditions, each sample (10 mL) was divided into low and high volumes (1.0 and

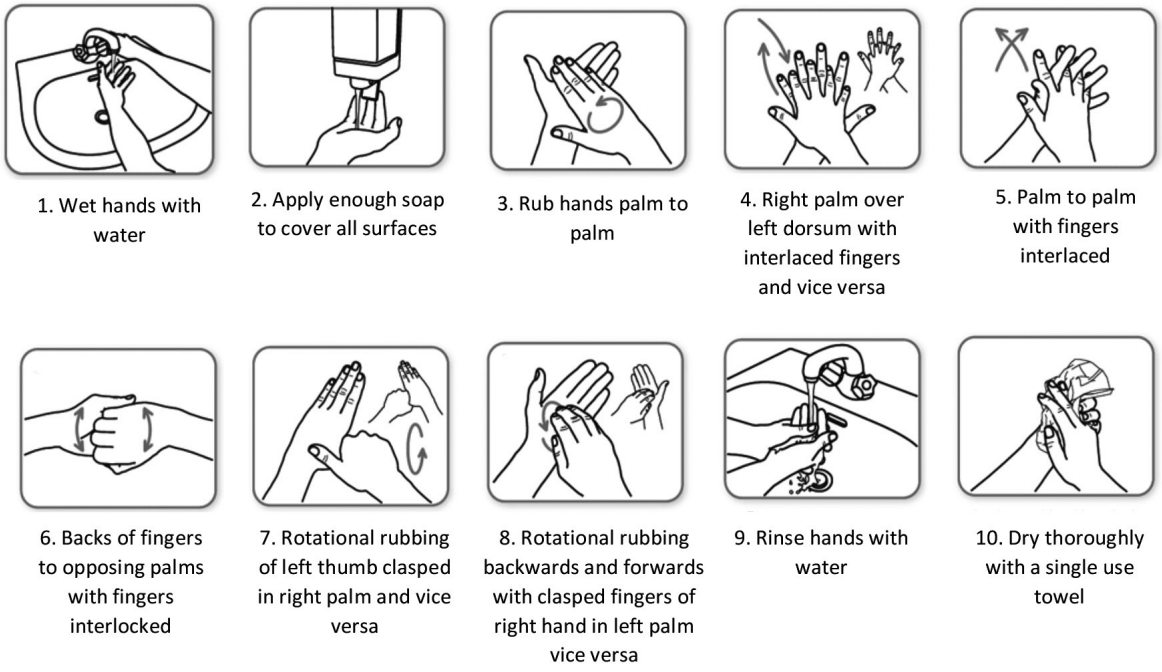

Figure 2. Modification of WHO guidelines on hand hygiene in health care. (WHO 2009)

9.0 mL, or 0.5, 1.0 and 8.5 mL), and passed through a 47-mm-diameter 0.45-µm cellulose filter. After filtration, the filter was placed on XM-G growth media (XM-G; Nissui Pharmaceutical Co., Japan) and incubated at 37°C for 20 ± 2h. The bacterial load on each media was read as colony forming unit (CFU) counts per hand. *E. coli* was determined by size and color of the colony (i.e., a blue and purple colony bigger than 1 mm). The *E. coli* bacteria count was converted to log CFU per hands. The changing of bacteria count was (the bacteria count before performed handwashing – the bacteria count after handwashing). The bacterial reduction was marked as positive results, while bacterial increased was marked as negative results.

Body measurements for nutritional status

Body weight and height for all children were measured to calculate their nutritional status. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 213; Seca, Germany), and body weight to the nearest 0.1 kg using a digital weighing scale (BC-754-WH; Tanita, Japan). With reference to WHO growth data, for children above 5 years old and adolescents, child nutritional status is determined by using z-scores from height for age (HAZ), weight for age (WAZ), and BMI for age (BMIAZ) (De Onis et al. 2007). However, to have comprehensive result of all nutritional status category in the Indonesian context, we used the first Indonesian growth chart as standards from Batubara et al. (2006) to calculate z-scores. From this, we classified children based on categories such as a z-score of less than -2 SD (Standard Deviation) as reflecting under-nutrition, between -2 SD until 2 SD as normal, and of more than 2 SD as over-nutrition. Z-score less than -2 SD of HAZ, WAZ and BMIAZ were used to indicate stunting, underweight, and thinness, respectively. In the other hand, z-score more than +2 SD for BMIAZ was used to indicate overweight.

1.4. Statistical analysis

First, we conducted descriptive analysis of mean values and percentages or prevalence. Second, Spearman rank correlation test was conducted between (1) time duration of handwashing and *E. coli* count after handwashing, and

Table 1. Participants characteristics.

Category	Male n = 24	Female n =17	WHO (2009)
Age	12.06	11.88	
Height for age z-score (HAZ)	-0.35	-0.02	
Weight for age z-score (WAZ)	-0.50	-0.30	
BMI for age z-score (BMIAZ)	-0.72	2.06	
Prevalence of child thinness (%)	6.00	0.00	
Prevalence of child overweight (%)	4.00	1.00	
Before (log CFU/hand)	1.69	1.58	
After (log CFU/hand)	1.23	0.99	
Bacterial reduction (log CFU/hand)	0.70 ± 0.45		
	0.65 ± 0.44	0.79 ± 0.48	
Bacterial increase (log CFU/hand)	- 0.59 ± 0.38		
	- 0.81 ± 0.45	- 0.38 ± 0.16	
Handwashing score (step)	5.60	6.17	10
Total time of duration (sec.)	48.87	53.00	40-60
Time 1st step (sec.)	4.70	4.76	NA
Time 3rd-8th steps (sec.)	7.17	7.65	15-20
Time 9th step (sec.)	14.95	13.06	NA

This table was presenting as a mean value or percentage
Bacterial reduction is among children who had reduced *E. coli* count after handwashing n =35 (boys = 21; girls = 14)
Bacterial increase is among children who had increased *E. coli* count after handwashing n = 6 (boys = 3; girls = 3)

(2) handwashing score and *E. coli* count after handwashing. Third, comparisons analysis was done between (1) *E. coli* count before and after handwashing using paired t-test, and (2) child nutritional status and child handwashing skill (10 steps) using t-test. All statistical analyses were performed using IBM SPSS 23 for Windows.

1.5. Ethical considerations

This study was approved by the Ethical Review Committee of The Faculty of Health Sciences, Hokkaido University (No.17-13). This study was carried out under a Memorandum of Understanding (MoU) between the Research Institute for Humanity and Nature (RIHN) and the Indonesian Institute of Sciences (LIPI). All purposes and contents of this study were explained to participants. Parents allowed their children to participate in this study by replying with written informed consent.

2. Results

2.1. Characteristics of participants

Children were the 6th grade elementary school students with age ranging from 11 to 14 years. Ten percent of the children were more than 12 years of age while most were between 11 and 12 years. Those 73% of children lived in households with a monthly income of less than 2,000,000 rupiahs (139.02 USD) per month and 56% lived in as extended family (data not shown). Referring to the first Indonesian growth chart, overall child nutritional status fitted within the normal range for both male and female participants. Whereas based on their mean value, female children tended to have higher nutritional status than male children. Moreover, based on their prevalence, 6% of underweight and 4% of overweight children were male (Table 1). In addition, we did not find a significant association of either child handwashing skills or nutritional status with socio-economic conditions.

Figure 3. Bathroom at school. (Taken by the author)

In general, children used 2 sites for handwashing at school: (1) in the bathroom using a water bucket and scoop, and (2) using tap water outside the bathroom, also without a sink. 1 sink that used to be a common handwashing site was found broken and lacking in maintenance. Obtaining clean water in the school was also difficult since we found the water pump was broken. Furthermore, 2 bathrooms that often have been used as a handwashing site were in poor condition. The bathrooms were also used by school security for washing clothes and dishes, thus became dirt and lacked space (Figure 3).

2.2. Child handwashing skills

Our results showed that children had greater skill in first 5 steps of handwashing, which is wetting hands before lathering up, until palm to palm with fingers interlaced. Skill then decreased sharply for the 3 later steps (Table 2). Unfortunately, not all children could accomplish hand drying after rinsing their hands with water following lathering. Among the overall 10 steps of handwashing score, on average, children were aware of performing 6 steps (Table 3). Children had different preference for tools and soap for handwashing. Regarding tool preferences, 85% of the children chose tap water and 15% of the children chose a water bucket with scoop. Regarding soap preferences, 59% of the children chose bar soap while 39% chose liquid soap. However, their preference for tools or soap had no significant association with the *E. coli* count on hands after handwashing.

2.3. Handwashing time duration, *E. coli* count, and nutritional status

Our findings showed that a longer time duration for wetting hands with water before lathering (1st step) was significantly associated with lower *E. coli* count after handwashing (Table 3). Handwashing was proven to significantly change *E. coli* count on children's hands (Figure 4), where the mean value of log *E. coli* count reduction is 0.70 log CFU/hand for participants who decreased the *E. coli* count. Unexpectedly, we found that in 14.6% of the children handwashing increased the *E. coli* count. Such children were found to not perform the hand drying step and tended to dry their hands using their school uniform.

The difference mean value of child nutritional status such as HAZ, WAZ, and BMIAZ for children who performed and not performed hand drying after handwashing (Table 4). The children who dried their hands properly with a single clean paper towel after handwashing had a significantly higher nutritional status in terms of HAZ and WAZ than the children who skipped this step. A similar trend was indicated for BMIAZ but this was not significant.

Table 2. Children handwashing step accomplice.

Handwashing step	Observed n (%)	Not observed n (%)
1st Step	37 (90)	4 (10)
2nd Step	39 (95)	2 (5)
3rd Step	37 (90)	4 (10)
4th Step	25 (61)	16 (39)
5th Step	23 (56)	18 (56)
6th Step	1 (2)	40 (98)
7th Step	2 (5)	39 (95)
8th Step	2 (5)	39 (95)
9th Step	41 (100)	0
10th Step	32 (78)	9 (22)

Table 3. Time allocation for handwashing practice and total bacteria after handwashing.

Outcome	Variables	Mean	Correlation
E. coli count after handwashing (log CFU/hand)	Time 1st step (sec.)	4.70	- 0.33*
	Time 3rd - 8th step (sec.)	7.40	0.06
	Time 9th step (sec.)	14.20	0.13
	Total time duration (sec.)	50.60	-0.28
	Handwashing score (step)	5.80	-0.15

*significant correlation by Spearman correlation test, $p < 0.05$

Table 4. Child nutritional status in relation to performing 10th step.

Outcome	10th Step		p-value
	Observed	Not observed	
HAZ	-0.03	-0.89	0.02
WAZ	-0.24	-1.03	0.04
BMIAZ	-0.50	-1.26	0.18

*significant difference by t-test, $p < 0.05$

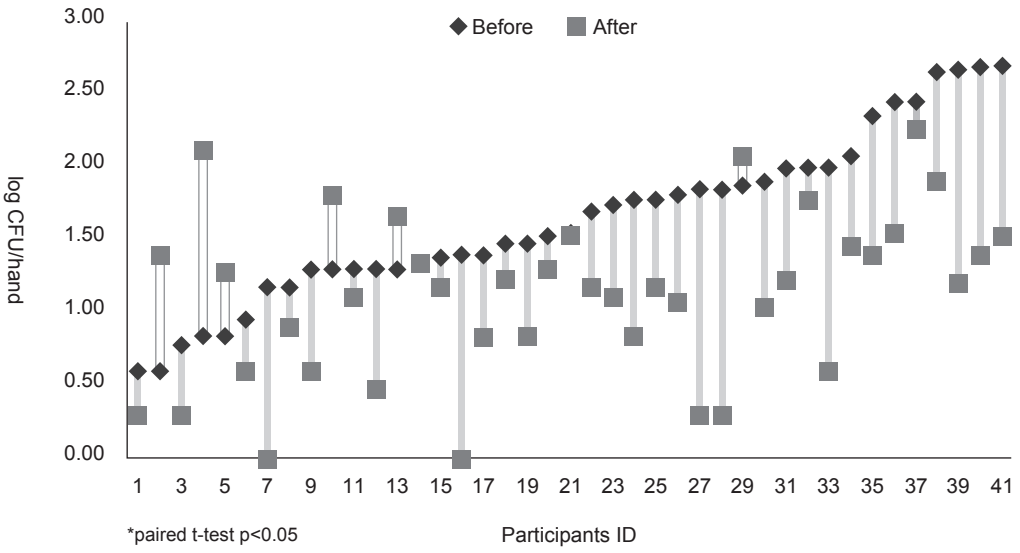

Figure 4. *E. coli* count on hand before and after handwashing for all children.

3. Discussion

3.1. Children's handwashing skills

Our results showed that 90%, 61%, and 56% of the children were accomplished in handwashing skills from the 3rd until the 5th step, respectively. This then declined sharply through the 6th to the 8th step to 2%, 5%, and 5% respectively (Table 2). A similar study conducted in medical staff (nurses, physicians and auxiliaries), found a similar pattern with greater handwashing skill in the initial steps, then decreasing for further steps to 70.6%, 30.3%, and 40.9% (Arias et al. 2016). However, elementary school children in this study showed much lower overall levels of handwashing skill than those medical staff. This may be because elementary school children rarely perform this skill in their daily life due to forgetfulness or time lacking (Lopez-Quintero et al. 2009). This result showed that elementary school children's awareness of handwashing steps is low and that handwashing guidelines from the WHO are not well implemented in elementary school children.

3.2. Children's handwashing time duration and *E. coli* count

Handwashing was proven effective in eliminating *E. coli* on hands (Figure 3) since in 85% of the children total bacteria were reduced after performing handwashing. We found that a longer total time duration to complete all steps of handwashing tended to produce larger reductions in *E. coli* count, although significant differences were not observed (Table 3). We found children typically spent less than 20 seconds on lathering (Table 3), lower than the time were found in a previous study (Jensen et al. 2017). Thus, it made bacteria reduction in this study also lower than that study. According to that study, 20 seconds spent on lathering using antimicrobial soap reduced the *E. coli* count on hands by 1.95 log CFU/hand. A similar study in school children revealed an *E. coli* count reduction of 0.66 log CFU/hand after rubbing hands with non-antimicrobial soap for 15 seconds (Pickering et al. 2010). Therefore, allocating sufficient time for handwashing using antimicrobial soap is necessary for greater bacteria reduction (Pickering et al. 2010).

Moreover, spending more time pouring water onto hands before applying soap and before lathering significantly lowered *E. coli* count after handwashing (Table 3). The mean value for this 1st step was 4.7 seconds in the current study, although there are no specific guidelines available. Considering this result, 39% of the children spent less than 5 seconds on pouring water and 10% of them skipped the 1st step and went directly to the 2nd step. In other words, children needed to spend more time pouring water to perform both wetting hands before handwashing, and rinsing hands after lathering, for further bacterial reduction. Therefore, children need to apply more water for a longer total duration of handwashing to prevent contamination exposure from fecal-hand or fecal-mouth transmission (Oswald et al. 2008). However, Bandung is even not facing water scarcity, but having problem with access to sufficient quantities of water (Marcotullio 2007). This matter also presents a challenge for children to perform through handwashing.

3.3. Drying hands, *E. coli* count, and child nutritional status

Result showed 6 cases where children had increased *E. coli* count after handwashing (Figure 4). Those children were observed not performing 10th step correctly but they were drying their hands with their school uniforms (Table 2). The main possibility for the source of contamination is their school uniforms, which are exposed to bacteria while playing outdoors. A similar concern was found in a study of nursing students who had bacterial contamination during their shift in the hospital; not changing their uniform increased contamination (Callaghan 1998). Furthermore, wet hands after insufficient drying can encourage bacteria to develop more rapidly after touch-contact bacterial transfer, even after handwashing (Huang et al. 2012). Therefore, hand drying should not be neglected as an integral step of handwashing (WHO 2009) and we suggest using a single clean paper towel to

dry hands for the most effective reduction of bacteria (Huang et al.2012).

Moreover, children who were observed performing hand drying had better nutritional status in terms of HAZ and WAZ, but not in terms of BMIAZ (Table 4). Since children who failed to perform hand drying had fecal bacteria contamination on their hands, they also have a higher possibility of fecal oral transmission that leads to repeated gastroenteritis or severe diarrhea. Thus, it could cause nutrient malabsorption resulting in faltering growth (Korpe and Petri 2012). This finding is also in line with that of our previous study, where not performing hand drying significantly increased the risk of child stunting (Adjusted Odds Ratio (AOR): 2.37; 95% CI: 1.13-4.96) (Otsuka et al. 2018b). Therefore, fully accomplished handwashing skills are entirely necessary to prevent bacteria transfer from hands which results in lower child nutritional status.

3.4. Limitations

This study was conducted mainly through observation and direct assessment. It was able to address scientific questions in relation to handwashing skills, total *E. coli* count, and the nutritional status of elementary school children. However, there were some limitations to this study. First, as a cross-sectional study with a small sample size we could not determine causal relationships for all variables related to the study indicators. Second, we did not record children's illnesses for previous years as a direct cause of lower child nutritional status. Despite this, we believe that further studies on hand hygiene and child nutritional status are potential fruitful research areas since handwashing is not only critical for healthcare workers but also for children. Further research with a larger sample size, using a longitudinal study design, and assessing children's hygiene behavior, is needed to provide more robust data with regards to the importance of handwashing skills for child health.

Conclusion

This study revealed that the available guidelines are not well understood or implemented. Factors that affect total bacteria reduction after handwashing are: (1) time duration for handwashing, especially for wetting hands before lathering; and (2) performing comprehensive handwashing skills including drying hands with a single paper towel. Although handwashing is not directly related to child nutritional status, improper hand drying which results in hand contamination may lead to a lowering of child nutritional status.

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