Serial Measurements of Soap Weights and Soap Availability to Describe Handwashing Behavior

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Abstract. Available measures of handwashing are prone to bias. We tested the feasibility and reliability of weighing soap at repeated visits and subtracting the measured weight from the prior weight to assess daily per capita soap consumption in a low-income community in Dhaka, Bangladesh. Fieldworkers approached 220 households twice weekly over 2 months. They interviewed participants, weighed soap, and assessed hand cleanliness and the presence of a handwashing station. Respondents used bar soap (91% [201]) and laundry detergent cakes (39% [85]) for handwashing as well as for bathing and laundry. Ninety-eight percent of households had bar soap present on at least one visit, although only 50% had bar soap at every visit during the 2-month period. Fieldworkers observed a soap fragment on the wall near the latrine in 27% (470) of visits. Households consumed a mean 1.5 g of bar soap and 3.2 g detergent cake per person per day. Daily per capita soap consumption was similar in households visited by fieldworkers after different intervals (2, 3, 4, or 5 days). Soap consumption was not associated with household wealth, education of the household head, the presence of a handwashing station, the presence of water or soap at a handwashing station, or palm inspections of the mother or child. Soap weight measurements were an objective, reliable measure of soap consumption that provided different information from other handwashing indicators. The frequent use of a soap product for purposes other than handwashing complicates using soap consumption as a handwashing measure.

INTRODUCTION

Handwashing with soap can reduce diarrhea¹ and respiratory illness.^{2,3} Effective strategies to promote handwashing could reduce the burden of respiratory and diarrheal diseases among millions of households in underprivileged communities.^{4–8} One of the barriers to developing and iteratively improving large-scale interventions to improve handwashing behavior is the absence of practical, valid, low-cost methods of measuring handwashing.⁹

Current approaches to measure handwashing have serious limitations. Self-reported handwashing behavior is invalid.^{10–12} Structured observations are expensive, and the presence of an observer alters behavior and biases measurement.^{13–16} Measurements of hand contamination are so highly variable that they require a large sample size,^{17–19} and the presence of a handwashing station with soap and water has not been consistently associated with a reduced risk of diarrhea and respiratory infection.^{20–22} A low-cost, accurate approach to characterize handwashing behavior would be useful for developing and evaluating handwashing behavior change interventions.

This study examined the feasibility and reliability of serial soap weights as a new measure of handwashing among low-income households in Dhaka, Bangladesh. We used multiple, brief, closely spaced visits (within a few days) to a household to assess the availability, location, and weight of the household's handwashing products. Brief home visits that neither provide a product nor observe behavior for hours may be less likely to induce reactivity than structured observation. Serial soap weights avoid overreporting of socially desirable handwashing behavior because data are based on objective observations and measurements by field staff. The method uses

simple inexpensive scales to measure weight, which have a low failure rate.

The objective of this study was to measure serial soap weights in a population with a high incidence of diarrhea and respiratory disease, assess the information gained, and compare soap weight differences with other measures of handwashing.

METHODS

Study population. The study was conducted between February and April 2010 in the densely populated low-income Kamalapur neighborhood in southeastern Dhaka, the capital city of Bangladesh. The study participants were drawn from the control population of a concurrent case-control study on handwashing and risk of influenza and pneumonia in children aged < 5 years.²³ The control population was drawn to be a representative of Kamalapur households with young children.

Data collection. The serial soap weight study used 15 experienced fieldworkers who were fluent in spoken and written Bengali. Fieldworkers received classroom and field training using the data collection instruments.

Enrollment. A list of potential households was distributed to fieldworkers, who visited as many households from their list as possible during the consenting period. If an adult household respondent reported no plans to move or leave the area within the subsequent 6 weeks and would be available for twice weekly interviews, the fieldworkers introduced the research study and sought informed consent. To minimize potential reactivity, fieldworkers described the research as a study of personal-care product ownership and use patterns. Fieldworkers asked respondents about many commonly used items, including shampoo, hair oil, toothpaste, bar soap, and powdered soaps.

We randomly divided enrolled households into two groups. Fieldworkers visited Group A each Sunday and Wednesday and visited Group B on Tuesdays and Thursdays. In the rare case that a respondent expressed a preference for visit days, fieldworkers accommodated their request.

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Visits. At the initial visit, the field staff confirmed previously collected study information on household demographics and collected personal-care product use and replacement patterns. Fieldworkers visited households twice a week over 4 weeks at intervals of 2, 3, 4, and 5 days; all missed visits were made up within 1 or 2 days, if possible.

At each visit, fieldworkers inventoried the predetermined list of household personal-care products (bar soap, laundry detergent, dishwashing soap, toothpaste, ash, hair oil, and shampoo) and asked respondents to identify their main handwashing product and all products used for handwashing by household members. For each available product, the fieldworker characterized its moisture content (dry, moist, wet, and semi-liquid), container type, and whether the item was mixed with ash (a common local practice, particularly for dishwashing soaps). If the container was weighed with the product, the fieldworkers noted whether the container had been changed since the last visit. Fieldworkers asked respondents whether they anticipated replacing any items before the next fieldworker visit.

Fieldworkers weighed soap and other household products less than ~200 g using small digital scales with a maximum capacity of 500 g and 0.1 g increments and heavier items with larger digital kitchen scales (maximum weight 5 kg, 1.0 g increments). Fieldworkers inspected the wall near the latrine and assessed if there was a small scrap of bar soap affixed to the wall.²⁴ If present, fieldworkers measured the length, width, and depth of the soap fragment using a ruler. Fieldworkers conducted hand inspections and noted the degree of visible soiling (visible dirt, unclean, and clean) on the respondents' palms, finger pads, and nails, and, if available, the hands of a child less than 5 years of age.¹² Fieldworkers observed the presence of soap and water at the main handwashing station.

We adopted a habit strength index developed by Verplanken and Orbell²⁵ to assess the study populations' handwashing habit. On the final visit, fieldworkers administered a 14-item self-report habit index that asked about handwashing with soap across five aspects of habitual behavior: how frequently they wash hands with soap, their lack of awareness of engaging in the practice, their difficulty in avoiding handwashing with soap, the efficiency of the behavior, and how much they identify themselves by the behavior. The respondents replied using a 7-point Likert scale ranging from 1 (agree very strongly) to 7 (disagree very strongly).

Data management and analysis. We merged the questionnaire and soap weight data with previously collected demographic and socioeconomic data from the case-control study. We used the first principal component of an index of durable assets to create wealth quintiles.^{20,26}

We calculated the amount of soap product consumed as the difference in soap product weights between two visits. We converted soap product weight differences into gram soap consumed/day/per capita. The total number of persons in the household, regardless of age, was considered when calculating per capita soap use in grams/day. We included soap weights from consecutive visits in analysis if there were no observed or reported soap replacements and no soap container changes (if the container was weighed with the soap). We assumed that negative values in soap weight differences represented errors in documentation of reported or observed replacement, container changes, or changes in soap water content and so were dropped from the analysis.

We defined consistent handwashing soap availability as the presence of the main handwashing product at every follow-up visit. We summarized the score for the self-reported habit index and use this as a continuous variable to estimate habit strength.

We used multiple logistic regression to explore associations between soap weights and other handwashing proxy measures. For estimating *P* values and 95% confidence intervals (CIs) for coefficients, we used robust standard error to account for the clustering due to repeated measures within the same household.

Ethics. All participants provided informed consent for participation in this study. This study protocol was approved by the icddr,b Ethics Review Committee (PR 2008-068).

RESULTS

Of the 473 households screened for the study, 468 were eligible for enrollment. Fieldworkers attempted to visit the first 420 households on their list (89%). Two hundred thirty-seven households agreed to participate. Of the remaining households, 145 addresses could not be located, 21 families had moved away, 14 did not have an adult respondent present to provide consent, and four refused. Of the 237 who consented, 220 were present and completed the initial visit. Of these 220, four households dropped out after one or more visits. Fieldworkers completed 220 initial visits, 1,218 follow-up visits, and 215 final visits (median of eight visits per household).

Male heads of households completed an average of 9 years of formal education; 99% of households had electricity and 80% owned a mobile phone (Table 1).

Respondents most commonly mentioned bar soap as the form of soap they used for handwashing (*N* = 201; 91%), although they also used it for bathing (Table 2). Respondents also reported using laundry detergent cake and powder to wash hands.

Bar soap availability in households was confirmed by fieldworker observation in 86% of household visits (Table 3). Nearly every household (98%) had bar soap present on at least one of the household visits, although only 50% of households had bar soap at every household visit. Similarly, the availability of other soap products varied both across households and within the same households on repeated visits (Table 3).

TABLE 1
Characteristics of study households Dhaka, Bangladesh 2010

	Frequency <i>N</i> = 218*	Mean/ percentage
Household size	218	Mean
Children aged < 5 years in household	318	5.2
Education of male household head (years)	208	1.5
Education of female household head (years)	10	8.8
Rooms in house (excluding bathroom)	218	3.5
Rents home	174	1.5
Electricity	217	Percentage
Working color television	136	80
Working refrigerator	70	99
Mobile phone	175	62
		32
		80

* Household demographic information was unavailable on two households.

TABLE 2
Use patterns of handwashing soap in urban low-income households ($N = 220$) in Dhaka, Bangladesh, 2010

Product	Household reporting soap type used for handwashing* ($N = 220$) n (%)	Additional uses of products identified for handwashing			
		Bathing n (%)†	Hair washing n (%)†	Laundry n (%)†	Dishwashing n (%)†
Bar soap	201 (91)	200 (99)	90 (45)	5 (2)	3 (1)
Laundry detergent cake	85 (39)	15 (18)	16 (19)	85 (100)	12 (14)
Laundry detergent powder	21 (10)	0 (0)	0 (0)	20 (95)	18 (86)
Liquid soap	3 (2)	0 (0)	0 (0)	0 (0)	0 (0)

* Multiple answers permitted.

† Row percentage, that is, denominator are the households who reported using this soap product for handwashing.

Fieldworkers observed a soap fragment on the wall in 27% (470) of visits. The soap fragments averaged 5.0 cm length, 3.8 cm height, and 3 mm depth.

Households with consistent handwashing soap availability were more likely to be in the highest wealth quintile than in the lowest quintile (OR 1.9; 95% CI: 1.4–2.4). Adjusting for the wealth quintile, compared with households where soap was not consistently available, households with consistent soap availability were more likely to have soap present at the handwashing station (OR_{adj} 1.4; 95% CI: 1.1–1.7), more likely to have a handwashing station in or contiguous to their dwelling (OR_{adj} 1.2; 95% CI: 1.1–1.3), more likely to identify cheaper detergent rather than bar soap as the main handwashing product (OR_{adj} 2.2; 95% CI: 1.6–2.9), and more likely to have toothpaste (OR_{adj} 2.4; 95% CI: 1.9–2.9) and shampoo at home (OR_{adj} 1.8; 95% CI: 1.4–2.3). Consistent availability of soap for handwashing was not associated with scores for the key components of habit as assessed by our 14-question habit tool administered during the final visit.

Of the 1,139 visits with at least one bar soap measure, 348 (31%) were ineligible for soap consumption analysis either because of replacement of the previously weighed bar of soap with a new bar (311; 27%) or because of a negative value (37; 3%). Of the 705 visits with at least one laundry cake soap weight, 332 (47%) were ineligible for consumption analysis either because of replacement (310; 44%) or because of a negative value (22; 3%). The longer the interval between soap weight measurements, the lower the proportion of households who had data eligible for analysis (Table 4).

The fieldworkers' observation of soap replacements was similar to the participants' reports. Among the 429 occasions when study participants reported replacing their bar soap since the last visit, fieldworkers judged that the observed bar was a replacement on 417 (97%) occasions.

Similarly, of the 460 occasions when study participants reported replacing their detergent cake, fieldworkers judged that the observed bar was a replacement in 455 cases (99%).

Among household that had the same bar of soap available on consecutive visits and so provided analyzable soap weight differences, households consumed a mean of 1.5 g of bar soap per person per day. The measurements of per capita soap consumption was similar in households followed up after 2, 3, 4, or 5 days (Table 4). There were many fewer observations after only a single day. Participating households consumed a mean 3.2 g of detergent cake per person per household per day. Intervals between 1 and 3 days had higher mean per capita detergent cake consumption compared with intervals 4 days or longer (3.5 g versus 2.3 g, $P = 0.01$) (Table 4).

When soap was available, the mean per capita bar soap consumption was slightly lower in the poorest wealth quintile, but none of the consumption in any of the wealthier quintiles was significantly higher than that in the poorest quintile (Table 5). Although the wealthiest quintile had the lowest per capita detergent cake consumption, there was no clear pattern in detergent cake consumption by wealth. There was no consistent association between the education of the household head and per capita soap consumption (Table 5).

Soap consumption was not associated with other rapid measures of handwashing, including the presence of a handwashing station, the presence of water or soap at handwashing station, or palm inspections of the mother or child (Table 6). Soap consumption was also not associated with a handwashing habit as measured by a validated 14-question tool (Table 6).

DISCUSSION

The primary objective of this study was to assess the feasibility and reliability of serial soap weights as a measure of handwashing. Mean bar soap weight differences and soap use measured in grams/day/person were consistent over different interval lengths (2, 3, 4, and 5 days). Our results suggest that in these communities soap weight measurements separated by 2 days can provide accurate data about

TABLE 3
Observed soap product availability in urban low-income households, Dhaka, Bangladesh, 2010

Soap product	Household visits when soap product was observed ($N = 1,716$) n (%)	Number of households with soap product observed during at least one visit ($N = 220$) n (%)	Number of households with soap product observed at every visit ($N = 220$) n (%)
Bar soap	1,477 (86)	215 (98)	111 (50)
Second bar soap	165 (10)	36 (16)	11 (5)
Laundry detergent bar	1,005 (59)	179 (81)	45 (20)
Laundry detergent powder	1,118 (65)	196 (89)	62 (28)
Dish cake	359 (21)	71 (32)	13 (6)
Dish powder	63 (4)	26 (12)	0 (0)
Dish liquid	10 (0.6)	3 (1)	0 (0)
Liquid soap	33 (2)	7 (3)	2 (1)

TABLE 4
Soap weight differences and intervals between visits, Dhaka, Bangladesh, 2010

Interval length (days)	Bar soap				Detergent cake			
	Frequency	Data eligible for analysis* n (%)	Mean bar soap weight difference† (SE)	Median bar soap weight difference (IQR)	Frequency	Data eligible for analysis* n (%)	Mean detergent cake weight difference (SE)	Median detergent cake weight difference (IQR)
1	10	8 (80)	1.6 (0.7)	0.9 (0.4–2.5)	9	4 (44)	7.7 (4.8)	3.7 (1.9–13.6)
2	447	327 (73)	1.5 (0.07)	1.2 (0.7–1.9)	439	186 (42)	3.4 (0.2)	2.8 (1.2–4.6)
3	255	169 (66)	1.4 (0.07)	1.2 (0.7–1.7)	237	83 (35)	3.6 (0.8)	2.2 (0.8–4.4)
4	256	138 (54)	1.6 (0.2)	1.2 (0.7–1.9)	244	48 (20)	2.3 (0.3)	2.0 (0.9–3.4)
5	287	142 (49)	1.4 (0.09)	1.2 (0.8–1.7)	279	51 (18)	2.3 (0.3)	1.8 (1.2–2.9)
≥ 6	15	7 (47)	1.3 (0.2)	1.1 (1.0–1.7)	17	1 (0.6)	1.7 (0)	N/A
Total	1,270‡	790 (62)	1.5 (0.05)	1.2 (0.7–1.8)	1,225§	373 (30)	3.2 (0.2)	2.3 (1.0–4.0)

IQR = interquartile range; SE = Standard error.

* Soap weight differences were included in analysis if there were no observed replacements, no soap container changes (if the container had to be weighed with the soap product), and the soap was used for handwashing. The soap weight differences were excluded in analysis if respondents reported that the soap had been finished and/or replaced within the interval.

† Soap weights are reported in g/capita/day.

‡ One thousand one hundred thirty-nine visits included at least one bar soap measure.

§ Seven hundred and five visits included at least one laundry cake soap weight.

soap consumption at the household level. Shorter intervals provided more data eligible for analysis, primarily because of fewer soap replacement events.

The main handwashing product was not consistently available in half of the participating households over the 4 weeks of this study. Although 86% of households had bar soap at any one time, only 50% of households had bar soap every time. This suggests that single cross-sectional measurements of soap availability risk misclassifying households' consistent soap ownership. It further suggests that if consistent soap use is important for interrupting infectious disease transmission, then strategies to promote maintenance of an uninterrupted soap supply may improve effectiveness in reducing disease transmission.

Households who reported using less expensive detergent were more likely to have a product available to wash hands than were households who reported using bar soap. Encouraging households to use detergent when bar soap is unavailable may increase the proportion of times when hands are washed with soap.

More than a quarter of households (27%) had a small fragment of bar soap affixed to the wall near the latrine, a practice noted in other settings in Bangladesh.²⁴ Because handwashing is a difficult habit to adopt and this is a practice that households are spontaneously adopting, future research should evaluate whether this small quantity of soap provides any benefit to improving hand hygiene and reducing transmission of fecal oral pathogens. Perhaps, such research could

identify strategies to improve the effectiveness of this common practice.

Nearly all respondents used their main handwashing product for at least one other purpose in the household. Of households using bar soap as their main handwashing product, 99% also used the same bar soap for bathing. All households who reported using laundry detergent as their main handwashing product also used it for washing clothes. Multiple uses for each soap product may contribute to the inconsistent availability of soap at the main handwashing station as households may sometimes keep their handwashing soap in a location more suited for its other uses.

The multiple uses of handwashing soap also complicate interpretation of the measured soap consumption as an indicator of handwashing behavior. A single episode of bathing where soap is used to wash the total body would be expected to consume more soap than several episodes of handwashing. Thus, small changes in bathing (or laundry) behavior would have much greater effect on soap consumption than a few more episodes of handwashing per day. The lack of association between per capita soap consumption and other handwashing measures may indicate that soap consumption is collecting useful orthogonal data that complement other imperfect measures of handwashing. Alternatively, soap consumption through activities other than handwashing may create so much high magnitude variability that soap consumption may not be a useful indicator of handwashing behavior. The absence of an association between a 14-question score on handwashing habits soap consumption supports this interpretation, although with the poor association between reported and observed handwashing behavior,^{10–12} the lack of association may also reflect inaccurate measure of handwashing habits. Moreover, this habit index has not been validated within this low-income population nor in the specific context of handwashing. Future research exploring soap consumption in other settings and the association between soap consumption and diarrhea may improve our understanding of the potential utility of this indicator. It is also conceivable that soap used for purposes other than handwashing may confer a health benefit.

Habit formation relies on repetition and context-response learning.²⁷ Environmental cues facilitate behavior and strengthen the link between context and response, leading to the development of habits.²⁸ Inconsistent soap availability

TABLE 5

Bar soap and detergent cake consumption by wealth quintile and education

	Mean bar soap consumption* (SE)	Mean detergent cake consumption* (SE)
Wealth quintiles (N)		
1 (44) poorest	1.2 (0.2)	3.5 (0.9)
2 (43)	1.7 (0.4)	5.4 (1.2)
3 (43)	1.8 (0.6)	2.8 (0.6)
4 (43)	1.5 (0.2)	4.1 (1.0)
5 (43)	1.4 (0.3)	1.5 (0.4)
Education of household head in years (N)		
0 (54)	1.5 (0.8)	2.8 (0.6)
1–4 (48)	1.5 (0.2)	4.6 (0.9)
6–8 (60)	1.6 (0.2)	3.7 (0.7)
9–13 (56)	1.4 (0.3)	2.6 (0.8)

* g/capita/day.

TABLE 6
Bivariate comparison of per capita soap consumption* with other measures of handwashing

Characteristic (referent condition)	Bar soap† observed (N)	Bar soap coefficient	P value	Detergent cake† observed (N)	Detergent cake coefficient	P value
Handwashing stations						
Handwashing station present (vs. absent)	784	0.08	0.91	372	-0.19	0.45
Handwashing station inside (vs. not inside)	784	-0.08	0.54	372	-0.71	0.26
At closest handwashing station						
Water present (vs. absent)	784	0.23	0.14	360	0.13	0.88
Soap present (vs. absent)	784	0.04	0.72	372	-0.56	0.28
Soap and water present (vs. absent)	784	0.036	0.75	372	-0.59	0.23
Hand inspections						
Mother's fingernails						
Observed dirty (vs. clean)	784	-0.03	0.78	372	-0.34	0.43
Mother's palms						
Observed dirty (vs. clean)	784	0.01	0.41	372	-0.81	0.31
Mother's finger pads						
Observed dirty (vs. clean)	784	-0.01	0.96	372	-0.72	0.32
Child's fingernails						
Observed dirty (vs. clean)	715	0.03	0.81	334	-0.29	0.48
Child's palms						
Observed dirty (vs. clean)	715	0.17	0.12	334	-0.77	0.18
Child's finger pads						
Observed dirty (vs. clean)	715	0.13	0.25	334	-0.56	0.3
14-Question tool to measure handwashing habit	776	-0.07	0.25	365	0.04	0.89

* Bar soap N = 784 observations in 205 households.

† Detergent cake N = 372 observations in 105 households.

means people cannot consistently practice handwashing with soap at appropriate times, thereby undermining habit formation. Handwashing campaigns that emphasize consistent soap availability at the main handwashing station and highlight that any soap type is acceptable for effective hand hygiene may be useful to strengthen habit formation and health outcomes.

In this study, wealthier households were more likely to have a handwashing station and a soap available. Independent of wealth, households with consistent soap availability were more likely to have toothpaste and shampoo at home. Ownership of multiple common toiletries may represent a broader commitment to hygiene behaviors. Linking handwashing promotion to other hygiene behaviors might improve practices.

This study has limitations. It is possible that the attention of study workers to household products and repeatedly weighing these items led to some change in consumption by the households. We attempted to obfuscate our interest in handwashing soap by measuring and weighing hair oil, shampoo, toothpaste, and other products. As we did not see progressive increase in soap consumption with repeated measures in the same household, this does not seem a major threat to validity.

A second limitation is that our estimates of soap and detergent consumption required availability of the same bar of soap or package of detergent at consecutive visits. When soap was not available, we did not estimate consumption. This method overestimates mean consumption, especially in low-income households, where soap was less consistently available. The similar measurements of soap per capita per day among low-income households compared with somewhat higher income households would be better interpreted as mean consumption on days soap was available, rather than as a robust assessment of mean consumption.

A third study limitation is that we recruited participants from a single low-income neighborhood of Dhaka, Bangladesh, and so these results may not be representative of other populations with other consumer product purchasing and use

patterns. Further research could evaluate this indicator in other populations.

This study demonstrated that weighing soap at two closely spaced household visits, measured with simple inexpensive equipment, was feasible and provided a reliable measure of soap consumption. The measured soap was a product that participants had purchased and self-identified as their main handwashing product, in contrast to measuring consumption of freely provided soap, which may overestimate soap use. Serial soap measurements avoids overreporting because data are based on objective observations and measurements by field staff. This approach provides unique data on soap ownership, replacement, range and prioritization of uses, and the availability of soap and water at handwashing stations over time. Drawbacks of the approach include the cost of a second visit to each evaluated household, and if households have replaced their soap since the last visit, a valid measure of consumption is not possible. Future research can assess the utility of soap weights as a supplementary measure of handwashing behavior.

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