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Evaluating children’s handwashing in schools: an integrative review of indicative measures and measurement tools

Abstract

Children are a key target of handwashing interventions as washing hands reduces the spread of disease and reliance on antibiotics. While there is guidance for evaluating handwashing with adults in other settings, this is lacking for children in schools. An integrative review of sixty-five studies where handwashing was measured in schools was conducted to establish which indicative measures (what is measured to evaluate the processes and/or impacts of, handwashing) and measurement tools (data collection instruments) have been applied to evaluate handwashing in schools, and under what circumstances. Further analysis highlighted different challenges when seeking to apply such measures and tools in schools, as opposed to other settings. It was concluded that indicative measures and measurement tools need to be appropriate to the organisational setting, the study participants, and research objectives. A summative analysis of relevant considerations is presented.

Introduction

Handwashing with soap can reduce the spread of disease (Curtis et al. 2009) and reliance on antibiotics (Bloomfield et al. 2007). NICE (Regis & Stone 2017) recommends that children should learn why it is important to wash hands. Many studies have now assessed children’s handwashing in school (see Summary of selected studies) and interventions to improve children’s hand hygiene in a school setting are still being developed. However, evaluating children’s handwashing remains a substantive challenge as *“The reality is this: there is no universally applicable method for measuring handwashing behavior that is valid, relevant, affordable, and logistically feasible for the various settings in which such behavior might*

need to be measured.” (Ram 2013). While there has been guidance written for assessing handwashing in hospitals (WHO (World Health Organisation); Haas & Larson 2007), the food industry (Conover & Gibson 2016), and low- and middle-income countries (Ram 2013), there is no guidance specifically developed for use in a school setting. We address the gap in this paper. This is necessary because conducting research with children in a school setting is different from conducting research with adults in other settings. Firstly, unlike in many hospital / food industry studies, those researching in schools tend not to come from the setting, and researchers cannot participate in schools as if they were a fellow child. Secondly, gaining access to settings may require considerable negotiation, and handwashing while important to the remit of health / food organisations is likely to be less so in schools where there will be other priorities. Thirdly, children are developing cognitively and data collection tools need to be appropriate for them. Moreover, children within a school may range in age from 4 to 18, and tools suitable for one age may be less so for another. Fourthly, extra care needs to be taken to ensure that children understand and consent to any research that involves them, not least because handwashing is a sensitive topic.

In this paper, studies are reviewed where children’s handwashing was evaluated. Indicative measures that have been used to evaluate the processes and/or impacts of, handwashing are identified. Next, moving on to examine the “how”, the measurement tools (i.e. the data collection instruments being used to measure) are identified. The suitability of these tools for measuring children’s handwashing, and how these tools have been employed in school settings according to the study objective are then considered. Finally, a summary of relevant considerations for use is presented. In this way it is hoped that this paper will be helpful to fellow researchers who need to evaluate handwashing in a school setting.

The review

Literature pertinent to the identified problem were systematically searched and synthesised following Whitemore and Knafl's (2005) five stages (problem identification, literature search, data evaluation, data analysis, presentation) to conducting an integrative review. This type of approach to conducting a systematic review was selected because integrative reviews are suitable for the incorporation of studies with diverse methodologies. Done well, integrative reviews can identify what is currently known about the topic, help develop theory, and influence practice and policy (Whitemore & Knafl 2005).

Problem identification (stage 1)

The first stage of any review is to identify the problem that the review is addressing and what aspects of the problem are / are not of interest (Whitemore & Knafl 2005). The problem that this review addresses is that evaluating children's handwashing remains a substantive challenge, and it is not clear which indicative measures and measurement tools should be applied, and when. An integrative review of the handwashing literature could reveal:

1. The indicative measures that have been used to evaluate children's handwashing in school settings
2. The tools (data collection instruments) that have been employed to undertake the indicative measures
3. The strengths and weaknesses of applying such tools with children in school settings
4. The contexts (i.e. the different study objectives and study designs) within which the indicative measures and measurement tools have been deployed

And then

5. Given 1-4, what the main considerations for use of such indicative measures and measurement tools in different contexts are

The focus of this paper is on data collection tools and how they have been used with children in school settings for different handwashing measures. Other aspects related to handwashing in schools are not reported but those evaluating handwashing in a school setting may wish to take these into consideration.

1. Measures and tools used to evaluate teachers' and parents' handwashing
2. Sampling techniques (e.g. number of children, school / class selection, and selection criteria)
3. Data analysis techniques (e.g. which statistical tests)
4. Confounding factors that could influence children's ability/propensity to wash their hands (such as whether handwashing facilities and products are available, or cultural beliefs)

Literature search (stage 2)

In an integrative review, how the review was undertaken (including which databases were used, the search terms employed, use of any additional search strategies, and the inclusion and exclusion criteria applied) must be clearly described (Whittemore & Knafelz 2005).

The review aimed for a comprehensive coverage of hand hygiene literature that could give a good overview of how handwashing is evaluated in schools. Science Direct, Medline, Web of Science and CINAHL as well as the university library catalogue and Google Scholar were searched for studies where children's handwashing was evaluated in schools. A combination of the following search terms was entered: hand hygiene, handwashing, hand washing, school, children, student, evaluation, intervention. The title and abstract of each citation was used to initially screen and select articles. The reference lists of selected articles were also examined for relevant studies.

The initial research resulted in the selection of 145 articles. The selection was further refined to 65 articles by the first author using the following inclusion / exclusion criteria:

1. Studies must include an evaluation of handwashing. Handwashing may be the only evaluation or may be part of a wider health evaluation.
2. If studies are related and no new indicative measures or measurement tools were used, then only the original study was selected.
3. The study must take place in a school setting (children age 4-18). Studies of pre-schools / kindergartens (under 5s) or university / college students (age 18+) were not included unless they were part of a wider study that included schools.
4. No limitations were placed on publication date or country location but studies had to be published in English (language spoken by authors).

Data evaluation (stage 3)

It is good practice to evaluate the risk of bias and quality of studies included in a review (Liberati et al. 2009). However, this is difficult in an integrative review where studies have employed diverse methods that will have different barometers of quality (Whittemore & Knafl 2005). Ideally, in an integrative review quality will be addressed in a way that is meaningful for that review (Whittemore & Knafl 2005).

In this review, no quality criteria were imposed while selecting the articles as the objective of this review was to assess how handwashing has been evaluated in schools. The focus of our study was not on judging the quality of individual study designs and enactment. Rather all relevant studies were collated to enable synthesis of the strengths and weaknesses of tools in addressing study objectives as reported by the authors of each study. Therefore, all studies that met the inclusion / exclusion criteria were included regardless of quality.

Data analysis (stage 4)

A systematic approach to data analysis should be determined prior to conducting an integrative review. Selected papers should be examined thoroughly without bias, and the results synthesised innovatively (Whittemore & Knafl 2005).

Two approaches were taken to analysing the data. The first approach was to analyse the studies quantitatively. To ensure methodological rigour and to allow comparison across the different studies, a predetermined classification scheme was used to extract the same data from each of the selected studies (Whittemore & Knafl 2005). Each study was examined for the measures and tools used to evaluate handwashing, as well as for study location, age of participants, and study objective. The extracted data was compiled into a spreadsheet. Next the spreadsheet was examined to identify patterns and relationships (Whittemore & Knafl 2005) between the studies and handwashing measures. Data were counted for which tools were being used for which measures (see Indicative Measures of Handwashing) and how the tool was deployed by each study (see Measurement Tools). The spreadsheet was also used to identify how the study objective influenced what tools were used (see Application of Measurement Tools). As the number of studies is small for conducting statistical tests we did not perform any, but percentages are reported.

The second data analysis approach was to identify the strengths and weaknesses of the different measurement tools. This was done by qualitatively synthesising the strengths and weaknesses of the measurement tools as reported in each of the studies. To further ensure that the data collection methods are suitable for use with children, this synthesis was also informed by incorporating literature that focuses on research methods with children. Suggestions on when to consider usage were made by giving consideration to how and why measurement tools have been used in the selected studies.

Presentation (stage 5)

In an integrative review, results should be reported in tables and diagrams in a way that contributes to a new understanding of the topic. Implications for practice should be stated, as well as the limitations (Whittemore & Knafel 2005).

The selected studies are documented in table 3 in the Appendices. The relationship between the indicative measures and measurement tools is illustrated, as is the frequency of use. How tools and measures have been used according to study objective is summarised in Table 2.

Finally, the findings are synthesised in Table 3 with recommendations made on when measurement tools should be employed. Limitations are also discussed.

Limitations

Although a large number of studies were identified and incorporated into this review, absolute coverage of all papers in this field cannot be claimed. This could mean that the number of studies using particular tools could be greater or proportionately fewer than reported. Furthermore, several studies were related and conducted by the same authors, and this too could skew frequency of tool use. Reliance on study authors' evaluations of strengths and weaknesses is a limitation in that their criteria and depth of analysis are variable.

The field is also developing and methods will change. Indeed, two of the studies identified used novel methods for tool development. It is also likely that as technology evolves new tools will become available or tools such as electronic counters become more commonplace.

Results

Summary of selected studies

65 studies that evaluated handwashing in a school setting were found (see Appendix A). The selected studies were conducted across the globe: 22 Africa, 18 Asia, 16 North America, 6 Europe, 2 South America, 1 Middle East and 1 Oceania (one study was conducted in both

Africa and Asia). Most studies were conducted in what would be considered primary / elementary schools (in the UK / US) with fewer studies conducted in what would be considered secondary / high schools (in the UK / US) - precise figures cannot be given as school systems vary according to country.

Indicative measures of handwashing

Handwashing can be indicated by evaluating the occurrence, frequency and quality of behaviour and / or a health outcome (Fig 1). Handwashing behaviour indicative measures include the occurrence of handwashing, as well as proxy measures such as product usage (e.g. soap consumption) and microbial presence. For handwashing outcomes, illness prevalence (tests that indicate sickness and / or determine the presence of particular micro-organisms in the body) is the only indicator used. Of the sixty-five school studies sampled, fifty-five (85%) studies measured behaviour and thirty-three (51%) outcome, with twenty-three (35%) measuring both.

Fig 1: Indicative measures and measurement tools used to evaluate handwashing

[Insert Figure 1 here]

Measurement tools

The measurement tools that were used and the frequency of use for each indicative measure is considered next (Fig 2). Overall, the most frequently used measurement tool was self-report (n=40), followed by indirect-report (n=28), observation (n=25), detection tests (n=13), and counting consumption (n=7). The same measurement tools (data collection instruments) were used across the different indicative measures, and the same measurement tool could be employed within each study to collect different measurement data.

- Counting consumption was used to measure (i) in six studies how much of a handwashing product has been consumed to indicate frequency of handwashing

behaviour (White et al. 2001; Morton & Schultz 2004; Nandrup-Bus 2009; Nandrup-Bus 2011; Gerald et al. 2012; Priest et al. 2015), and (ii) in one study how much medicine has been consumed to indicate a health outcome (Gerald et al. 2012).

- Detection tests were used to measure (i) in six studies microbial presence on the body and / or in the environment to indicate occurrence, frequency and / or quality of handwashing behaviour (Tousman et al. 2007; Sandora et al. 2008; Celik & Pancoe 2012; Randle et al. 2013; Grimason et al. 2014; Johansen et al. 2015), (ii) in two studies to measure quality of handwashing by testing for UV light sensitive residue (Lee et al. 2015; Krishna Kumar et al. 2016), and (ii) in five studies illness occurrence (e.g. helminth infection, influenza), illness variations (influenza A / influenza B) and intensity of infection to indicate health outcomes (Stebbins et al. 2011; Talaat et al. 2011; Bieri et al. 2013; Gyorkos et al. 2013; Al-Delaimy et al. 2014). Illness prevalence tests are used when an objective of a study is a reduction in a particular illness in the community. As such, the nature and scope of study design, and any related inferences about causes and effects, are highlighted as particular considerations where illness prevalence tests are being deployed.
- Observation was used to measure (i) in twenty-one studies occurrence, frequency and /or quality of handwashing to indicate behaviour (Pete 1986; Day et al. 1993; Guinan et al. 1997; Early et al. 1998; O'Reilly et al. 2008; Snow et al. 2008; Blanton et al. 2010; Graves et al. 2012; Patel et al. 2012; Bieri et al. 2013; Pickering et al. 2013; Xuan & Hoat 2013; Caruso et al. 2014; Pickering et al. 2014; Lee et al. 2015; Mohamed Moussa et al. 2015; Dreibelbis et al. 2016; La Con et al. 2017; Solehati et al. 2017; Chard & Freeman 2018; Grover et al. 2018; Parkinson et al. 2018), (ii) in two studies illness prevalence manifest in absence (Caruso et al. 2014; Chard &

Freeman 2018) and in two studies sickness (Bowen et al. 2007; Pickering et al. 2013) to indicate a health outcome.

- Self-report (children reporting on themselves) was used to measure (i) in thirty-one studies occurrence and frequency of handwashing to indicate behaviour (O'Reilly et al. 2008; Snow et al. 2008; Lopez-Quintero et al. 2009; Nandrup-Bus 2009; Nandrup-Bus 2011; Özyazıcıoğlu et al. 2011; Freeman et al. 2012; Patel et al. 2012; Setyautami et al. 2012; Bieri et al. 2013; Gyorkos et al. 2013; Pickering et al. 2013; Sibiya & Gumbo 2013; Xuan & Hoat 2013; Zhang et al. 2013; Al-Delaimy et al. 2014; Grimason et al. 2014; Peltzer & Pengpid 2014; Johansen et al. 2015; Mohamed Moussa et al. 2015; Zhou et al. 2015; Azuogu et al. 2016; Ranasinghe et al. 2016; Susanto et al. 2016; Tamilarasi et al. 2016; ALBashtawy 2017; Hetherington et al. 2017; Karon et al. 2017; Seimetz et al. 2017; Slekiene & Mosler 2017; Thakadu et al. 2018) (ii) illness prevalence manifest in absence in seven studies (Lopez-Quintero et al. 2009; Nandrup-Bus 2009; Nandrup-Bus 2011; Freeman et al. 2012; Gerald et al. 2012; Pickering et al. 2013; Chard & Freeman 2018) and / or sickness in four studies (Gerald et al. 2012; Freeman et al. 2013; Pickering et al. 2013; Zhang et al. 2013) to indicate a health outcome.
- Indirect-report (teachers and parents reporting on children) was used to measure (i) illness prevalence manifest in absence in twenty-three studies (Day et al. 1993; Dyer et al. 2000; Hammond et al. 2000; White et al. 2001; Guinan et al. 2002; Morton & Schultz 2004; Bowen et al. 2007; Tousman et al. 2007; O'Reilly et al. 2008; Sandora et al. 2008; Nandrup-Bus 2009; Blanton et al. 2010; Nandrup-Bus 2011; Stebbins et al. 2011; Talaat et al. 2011; Gerald et al. 2012; Lau et al. 2012; Azor-Martínez et al. 2014; Nicholson et al. 2014; Johansen et al. 2015; Lee et al. 2015; Priest et al. 2015; La Con et al. 2017) and / or in three studies sickness (Day et al. 1993; Gerald et al.

2012; Patel et al. 2012) to indicate a health outcome, and (ii) in three studies occurrence and frequency of handwashing to indicate behaviour (Tousman et al. 2007; Lau et al. 2012; Randle et al. 2013).

Fig 2: Use of measurement tools to evaluate handwashing in schools

[Insert Figure 2 here]

Strengths and weaknesses of measurement tools

As with any research instruments, measurement tools all have strengths and weaknesses. Moreover, the suitability of using these instruments when researching children needs consideration. In theory, any data collection method used with adults can also be used with children. In practice, there are some limitations relating to power relations, language and context (Ólafsson et al. 2013).

Counting consumption

The key strengths of counting consumption are that all handwashing events in a particular location can be captured, there are few ethical issues, and a Hawthorne effect (where a person changes their behaviour when being observed) is unlikely. However, it is not possible to distinguish between different types of events in the same location (e.g. whether hands are washed before eating / after defecation) and calculating consumption is often complicated in practice.

Although in theory any product that is consumed can be measured, for handwashing it is easier to measure soap consumption than drying consumption in schools for two reasons. Firstly, schools use different drying products (e.g. paper towels, roll-towels and electric dryers). Therefore, it is unlikely that drying can be meaningfully compared across multiple schools. Secondly, calculating usage is difficult: measuring hand towel roll consumption

involves calculations of roll diameters that is far from ideal, and we are not aware of any studies in any environment that measure electric dryers.

Manually measuring soap consumption also requires good relationships with schools as considerable access is required to monitor soap usage and / or schools need to help with data collection. An alternative approach is to deploy sensors to record the number of times soap has been dispensed combined with doorway sensors measuring the number of people entering the room. This approach has been used in other settings, notably in hospitals that may also deploy SMART devices (Dyson & Madeo 2017). However, the logistics of installing electronic equipment and the cost to do so is likely prohibitive in a school setting where interventions tend to run for relatively short periods and are not instrumental to the setting.

Detection tests

The key strengths of detection tests (illness prevalence, microbial presence and UV light testing) are they are not subject to recall or reactivity. Microbial presence and UV light testing can also be used to educate children by showing them the results of before and after tests. However, detection tests can be expensive, specialist equipment is required and all tests that involve the growth of microorganisms need access to a laboratory. While tests using UV light do not require the use of a laboratory, UV light can only indicate quality of handwashing. To identify microbial load and the presence of particular microbes, bacteria need to be sampled from children (e.g. using agar plates) and incubated. When planning detection tests the presence and intensity of microbes in the environment needs to be taken into consideration. The timing of microbial sampling is important. If there is a gap between a handwashing opportunity and the test, it may be unclear if the hands were washed or that a child simply picked up new microbes. Even if there is no gap between a handwashing opportunity and the test, results may be affected by the preceding event (e.g. defecation vs urination). For illness prevalence tests the intensity of an illness in a community needs to be

considered. In some communities, infections such as helminths are so widespread they are difficult to avoid despite handwashing; in Al-Delaimy et al.'s (2014) study children had to be treated with anti-worming medication prior to the intervention. For similar reasons, all children were tested for helminth infection prevalence post intervention, whereas in the influenza studies only children whose parents reported them having flu-like symptoms were tested (Stebbins et al., 2011; Talaat et al., 2011).

A further consideration is that for microbial presence and UV light tests the analysis is also subjective. For example, when testing children's hand prints using incubated agar plates, the plates still require interpretation as to the extent of bacterial colonies. A coding scheme and multiple coders can help ensure accurate and reliable readings.

Observation

A key strength of observations is that they have a "present orientation" so data collection is not biased by memory (Gorman & Clayton 2005). In hospital settings, observation is considered the most reliable handwashing measurement tool for determining healthcare workers handwashing compliance (WHO (World Health Organisation)). The data collected can be highly granular, for as well as observing who washes hands and when, technique can also be assessed.

However, there are several weaknesses with observation, many of which are exacerbated by the nature of handwashing and the school setting. Firstly, considerable access may be required. Observation is time consuming and it is difficult to observe all events, particularly spontaneous events. In addition, toilets are considered private spaces and particularly when located indoors it is problematic for adults to enter them. Secondly, there are validity concerns. Observations are liable to the Hawthorne effect. Furthermore, handwashing is a social norm (Curtis et al. 2009) and those observed are even more likely to adapt their behaviour in the presence of others. In other settings the observer effect can be mitigated by

the researcher joining in with everyday life within the setting but clearly a researcher cannot pass off as a child and school toilet spaces tend to be adult-free spaces.

Handwashing observers can either sample children or events. Sampling by child is less common than sampling by event because it is time consuming and difficult to do covertly. It has the advantage though that the impact of an intervention can be evaluated for each child (Solehati et al. 2017) and all of a child's handwashing events can be evaluated (Xuan & Hoat 2013). Some studies that have employed overt observations asked children to demonstrate how they wash their hands both before and after interventions to determine effectiveness (O'Reilly et al. 2008; Blanton et al. 2010; Patel et al. 2012; Solehati et al. 2017). Event sampling (e.g. observing handwashing in particular places such as toilet facilities / classroom / dinner hall) is less time consuming but does not capture individual children's practices and may result in an unrepresentative sample. It is also difficult to observe multiple children simultaneously, yet in a school setting facilities are often used *en masse*.

Observations are usually structured against a list of pre-determined events so that the data can be analysed quantitatively. Some studies only record if hands are washed (e.g. Graves et al. 2012) whereas others recorded multiple events such as products (water, soap, towels) used, handwashing technique, time taken and the precipitating event (e.g. Day et al. 1993; Mohamed Moussa et al. 2015). However, combining event sampling with a lengthy structured observation particularly when facilities are used simultaneously may result in inaccurate recording of data. Recording accuracy can be improved through video monitoring. Furthermore, a longer time period can be observed as the time frame is no longer dictated by observer fatigue. However, what is recorded is still limited by the camera angle and fixed location of cameras. Although video monitoring is less on-site resource intensive than in-person observation there are still associated costs and practicalities related to the purchase, installation, maintenance and security of the equipment (Pickering et al. 2014). As yet there is

no consensus on whether video monitoring decreases (Pickering et al. 2014) or increases (Tudge & Hogan 2005, p. 109) the Hawthorne effect. Cameras can be concealed but ethically this is problematic particularly in a space that is ostensibly thought of as private but is a possibility in settings where handwashing facilities are located outside toilet facilities (Grover et al. 2018). Another ethical concern is whether children can be identified, particularly as sensitive data may be recorded. One solution is to record low resolution images (Pickering et al. 2014).

Self-report

Self-report surveys are low cost in terms of labour, and can be cheap and easy to administer in large numbers. Within one survey a wide range of data can be collected: (i) handwashing questions can be incorporated into a wider survey of health, (ii) questions can go beyond practice to consider knowledge and attitudes to handwashing, and (iii) different types of events can be covered (e.g. school / home, after defecation / before food). The unit of analysis is the child rather than the event (the usual unit for observation). This means that all handwashing events for each child can be assessed (Zhang et al. 2013), and the effect of an intervention on different groups of children can be evaluated. However, privacy concerns may mean that self-report data is collected anonymously (Hetherington et al. 2017). Self-report can be used in situations that would be difficult to plan observations for e.g. after blowing nose or that are particularly private such as before / after touching genitals (Azuogu et al. 2016).

There are several weaknesses with self-report, particularly with regard to validity.

Handwashing behaviour is habitual and may be performed sub-consciously (Curtis et al. 2009) which can lead to under reporting. Conversely handwashing is socially desirable and so can also be over reported (Curtis et al. 2009). Even in studies of adults it is unclear if self-report correlates with actual handwashing behaviour (Ram 2013), and validity issues are

likely compounded with young participants. Children do not have the same memory capacity as adults (Greig et al. 2013), and may answer questions even when they don't understand them (Saywitz 2003, p. 5). In a school environment there is already a power relationship between pupils and teachers, and children may feel they need to give the "correct" answer (Punch 2002). To be able to respond to questions children need "the cognitive abilities of language, thought and memory" (Greig et al. 2013) which will vary according to the age and ability of the child.

Indirect-report

Using adults to inform on children has been frowned upon in studies of children. Best practice suggests that children should report on their own experiences so that they are the subjects of research, not the objects (Christensen & James 2008, p. 1). In addition, results are likely to be misrepresentative as teachers and parents will not have access to all that children do (Ólafsson et al. 2013), particularly for handwashing that is often a private activity. However, indirect-report is primarily used in hand hygiene studies where relevant data already exists.

The preponderance of using indirect-report is possibly peculiar to school settings where absence data already exists. In many countries there are statutory requirements for schools to record absence data, and so schools may be able to supply this data with little inconvenience. This offers a considerable time saving for researcher and also means that children are not being disturbed from their lessons. As well, school absence data may be available for long time periods (e.g. one or two years). However, handwashing only influences particular types of absences (e.g. infectious diarrhoea but generally not non-communicable diseases), and the data schools record may not be sufficiently detailed. Furthermore, the accuracy of the data is a concern. To ensure greater accuracy and to collect more detail on type of absence, study teams may request schools collect particular data and train them to do so. Indirect report may

also be supported by phone calls to children, interviews with parents, and examination of nursing records.

Application of measurement tools to meet study objectives

Whether the study objectives influence the use of indicative measures and measurement tools is considered next (Table 1). Within the selected studies three reasons were given for evaluating handwashing:

- Identification of current practice. Studies may audit current handwashing practices, and / or they may identify barriers and behavioural determinants of handwashing. Studies that audit current handwashing practices are often part of a larger study that also identifies other health-related practices. Studies that identify barriers and behavioural determinants may use secondary data sets e.g. (Ranasinghe et al. 2016).
- Intervention assessment. Studies may assess whether the introduction of facilities, products, education and other information improves hand hygiene and /or health outcomes. As well, some studies may assess whether an increase in handwashing (through soap provision and / or mandatory programs) will lead to a health outcome (usually indicated by a reduction in absence) e.g. (Azor-Martínez et al. 2014).
- Tool development (TD). Studies may seek to develop new tools to assess hand hygiene.

It should be noted that intervention assessment studies are also identifying current practices and previous practice if a before and after methodology has been used. However, the scale of the studies is often different, with current practice studies usually assessing a greater number of children. Of course, current practice studies may also be a precursor to an intervention. Additionally, tool development studies may also occur as part of an intervention.

Table 1: Use of indicative measures and measurement tools according to study objective

[Insert Table 1 here]

Current practice

Not surprisingly, all seventeen studies concerned with identifying current handwashing practice measured handwashing behaviour, as it is identifying how and whether handwashing is practiced that is the purpose of these studies. One study additionally measured the connection between handwashing behaviour and sickness and absence, a health outcome (Lopez-Quintero et al. 2009). Self-report, the most frequently employed tool (Lopez-Quintero et al. 2009; Setyautami et al. 2012; Sibiya & Gumbo 2013; Xuan & Hoat 2013; Grimason et al. 2014; Peltzer & Pengpid 2014; Azuogu et al. 2016; Ranasinghe et al. 2016; Susanto et al. 2016; Tamilarasi et al. 2016; ALBashtawy 2017; Seimetz et al. 2017; Slekiene & Mosler 2017; Thakadu et al. 2018), was for current practice studies an attractive option for two reasons. Firstly, many studies were part of a larger study that also identified other health-related practices and within a single self-report survey a wide range of data can be collected. Secondly, many studies also had large sample sizes (e.g. (Seimetz et al. 2017) visited forty schools), making self-report much more attractive than observation that is more time consuming. Notably three of the four current practice studies that used observation to identify handwashing practices had relatively small sample sizes of between one and six schools (Pete 1986; Guinan et al. 1997; Xuan & Hoat 2013). Fifteen (88%) of the studies used just one tool, with twelve only using self-report (Lopez-Quintero et al. 2009; Setyautami et al. 2012; Sibiya & Gumbo 2013; Peltzer & Pengpid 2014; Azuogu et al. 2016; Ranasinghe et al. 2016; Susanto et al. 2016; Tamilarasi et al. 2016; ALBashtawy 2017; Seimetz et al. 2017; Slekiene & Mosler 2017; Thakadu et al. 2018) and three only observation (Pete 1986; Guinan et al. 1997; Parkinson et al. 2018). Two studies also supported self-report with either observation (Xuan & Hoat 2013) or detection tests (Grimason et al. 2014).

Intervention assessment

Intervention assessment studies measured either behaviour, outcome or both. In part, this reflects the diversity of interventions with some focused on changing handwashing practices and others on whether improved practices (e.g. mandatory handwashing) result in a health outcome. However, almost half of studies measured both behaviour and outcomes, and that the majority employed two (37%) or three (20%) tools, perhaps suggests that evaluating handwashing interventions is difficult either because the tools are unreliable or the effect sizes are small. For perhaps the same reason, there is considerable variation in tool use across the intervention assessment studies (unlike current practice and tool development).

Within a single study, the same tool could also be also used to collect more than one type of data. The most frequently deployed tool was indirect report (n=26). Twenty-three studies asked schools to supply them with absence data that schools had already collected (Day et al. 1993; Dyer et al. 2000; Hammond et al. 2000; White et al. 2001; Guinan et al. 2002; Morton & Schultz 2004; Bowen et al. 2007; Tousman et al. 2007; O'Reilly et al. 2008; Sandora et al. 2008; Nandrup-Bus 2009; Blanton et al. 2010; Nandrup-Bus 2011; Stebbins et al. 2011; Talaat et al. 2011; Gerald et al. 2012; Lau et al. 2012; Azor-Martínez et al. 2014; Nicholson et al. 2014; Johansen et al. 2015; Lee et al. 2015; Priest et al. 2015; Chard & Freeman 2018). Particularly for large scale interventions, collecting “ready-made” data offers a considerable time saving. Indirect report was also used in three studies to identify sick children (Day et al. 1993; Gerald et al. 2012; Patel et al. 2012) and to check if interventions were being implemented in schools according to the research design e.g. (Nandrup-Bus 2011). Self-report was the second most frequently employed tool (n=19). It was used to identify illness prevalence in seven studies (Nandrup-Bus 2009; Nandrup-Bus 2011; Freeman et al. 2012; Gerald et al. 2012; Freeman et al. 2013; Pickering et al. 2013; Zhang et al. 2013; Chard & Freeman 2018) with four of these using self-report to improve accuracy of the indirectly

reported absence data (Nandrup-Bus 2009; Nandrup-Bus 2011; Gerald et al. 2012; Chard & Freeman 2018). Fourteen studies identified handwashing practices using self-report (Lopez-Quintero et al. 2009; Setyautami et al. 2012; Sibiya & Gumbo 2013; Xuan & Hoat 2013; Grimason et al. 2014; Peltzer & Pengpid 2014; Azuogu et al. 2016; Ranasinghe et al. 2016; Susanto et al. 2016; Tamilarasi et al. 2016; ALBashtawy 2017; Seimetz et al. 2017; Slekiene & Mosler 2017; Thakadu et al. 2018). Seventeen studies identified handwashing practices using observation (Day et al. 1993; Early et al. 1998; O'Reilly et al. 2008; Snow et al. 2008; Blanton et al. 2010; Graves et al. 2012; Patel et al. 2012; Bieri et al. 2013; Pickering et al. 2013; Caruso et al. 2014; Lee et al. 2015; Mohamed Moussa et al. 2015; Dreibelbis et al. 2016; La Con et al. 2017; Solehati et al. 2017; Chard & Freeman 2018; Grover et al. 2018) with six studies combining self-report data with observation (O'Reilly et al. 2008; Snow et al. 2008; Patel et al. 2012; Bieri et al. 2013; Pickering et al. 2013; Mohamed Moussa et al. 2015). It was only in intervention assessments (as opposed to current practice) that observation (in place of self-report) was used to identify handwashing practices. It is perhaps the high granularity of this tool whereby the different effects of an intervention can be assessed that makes it attractive. Observation was also used to support illness prevalence assessments in four studies, either as sickness (Bowen et al. 2007; Pickering et al. 2013) or absence (Caruso et al. 2014; Chard & Freeman 2018).

Counting consumption was only employed by intervention studies, and all of these studies employed this tool in conjunction with other tools and measures. Six studies measured soap consumption as an indicator of intervention compliance (White et al. 2001; Morton & Schultz 2004; Nandrup-Bus 2009; Nandrup-Bus 2011; Gerald et al. 2012; Priest et al. 2015), with four of these studies introducing hand sanitiser as part of the intervention. One study (Gerald et al. 2012) also employed consumption as an indicator of illness prevalence. The objective of

this particular study was to determine if handwashing with sanitiser would reduce asthma exacerbations and so a reduction in asthma medication was a suitable measure.

Detection tests were primarily used to evaluate interventions (Tousman et al. 2007; Sandora et al. 2008; Stebbins et al. 2011; Talaat et al. 2011; Celik & Pancoe 2012; Bieri et al. 2013; Gyorkos et al. 2013; Randle et al. 2013; Al-Delaimy et al. 2014; Johansen et al. 2015; Lee et al. 2015). Illness prevalence tests were used when a study objective was a reduction in a particular illness. For example, (Bieri et al. 2013; Gyorkos et al. 2013; Al-Delaimy et al. 2014) test for helminths, and (Stebbins et al. 2011; Talaat et al. 2011) for influenza. Six studies used microbial presence as a proxy measure as to indicate whether handwashing had occurred and how effectively hands have been washed (i.e. the fewer microbes on a hand the more likely the hand has been washed well) (Tousman et al. 2007; Sandora et al. 2008; Celik & Pancoe 2012; Randle et al. 2013; Grimason et al. 2014; Johansen et al. 2015). Two studies used UV light testing to measure how well hands have been washed (Lee et al. 2015; Krishna Kumar et al. 2016).

Tool development

Only two tool development studies were identified. Both of these studies were appraising tools to evaluate handwashing behaviour. One study contrasted video surveillance with in-person observation; the results were comparable and new behavioural insights were also revealed (Pickering et al. 2014). In the other study, a technique to quantify handwashing technique was developed using UV light testing (Krishna Kumar et al. 2016).

Summary and considerations for use

In Table 2, the findings of this review are summarised, and then suggestions are made as to when to consider using the measurement tools based on their strengths and weaknesses, and how they have been implemented in prior studies.

Table 2: Summary and considerations for use

[insert Table 2 here]

Discussion

Different types of organisational settings have different constraints and practices that affect what measures are used and how tools are deployed. For example, rapid observation (observation of handwashing facilities) used as a proxy measure for handwashing (e.g. presence of soap considered an indicator of handwashing) in the home (Ram 2013) is not a suitable measure for group settings with shared facilities. Whereas absence used as an indicator of a health outcome appears to be bespoke to schools. In hospitals, direct observation, self-report and product usage are the three most common tools (Haas & Larson 2007) and in mid- to low developing countries observation, soap consumption, illness prevalence and self-report (Vindigni et al. 2011). While these same tools are used in school settings, the deployment and suitability is different. For example, observation is considered the gold standard for determining healthcare workers handwashing compliance (WHO (World Health Organisation)). However, in hospitals handwashing typically takes place in public spaces but in schools handwashing often takes place in private spaces, making access more difficult and observation much more ethically problematic.

Although some measures and tools are used more frequently than others (Figs 1 and 2), there is no commonly accepted approach to measuring children's handwashing in schools. Despite the many different approaches none are fail-safe, and so many studies use more than one tool and measure of either behaviour and / or outcome (Table 1). That there are so many different measures and tools for evaluating handwashing is a concern (Conover & Gibson 2016; Chard & Freeman 2018) as it makes it difficult to compare results across studies. Furthermore, because no measure can be relied on, where interventions results are non-significant if it is not clear if this is because the intervention failed, the intervention was poorly implemented,

or a failure of the measure itself. To be able to compare studies and to be able to depend on a measure, it is necessary to standardise measures and their tools (Conover & Gibson 2016; Chard & Freeman 2018). However, it is also clear from this review that measures and tools need to be appropriate to the organisational setting, the study participants and research objectives. As such this review offers the reader both overview and analysis of the current nature and scope of practice in this field, along with related considerations for use in particular contexts.

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Appendix A

Table 3: Handwashing evaluation in schools

[insert Table 3 here]

Legend

Age: To make comparison easier ages are reported rather than school grades / year groups.

Where a study has only reported grade / year group or been non-specific (indicated by *)

Wikipedia (particularly https://en.wikipedia.org/wiki/Educational_stage) was used to identify the age of the participants.

Tools: Counting Consumption (CC), Detection tests (DT), Observation, (O), Self-report (SR), Indirect report (IR)

Study objective: Audit of current practice (CP), Assess intervention (I), Tool development (TD).

Region: Middle East (ME), Asia (As), Europe (Eu), Africa (Af), North America (NA), South America (SA), Oceania (Oc)

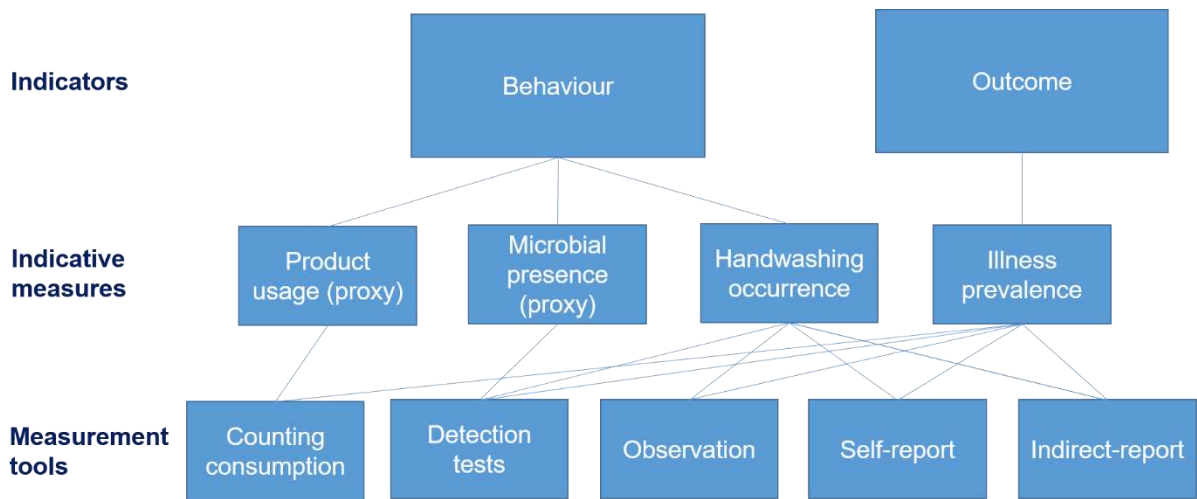


Fig 1: Indicative measures and measurement tools used to evaluate handwashing

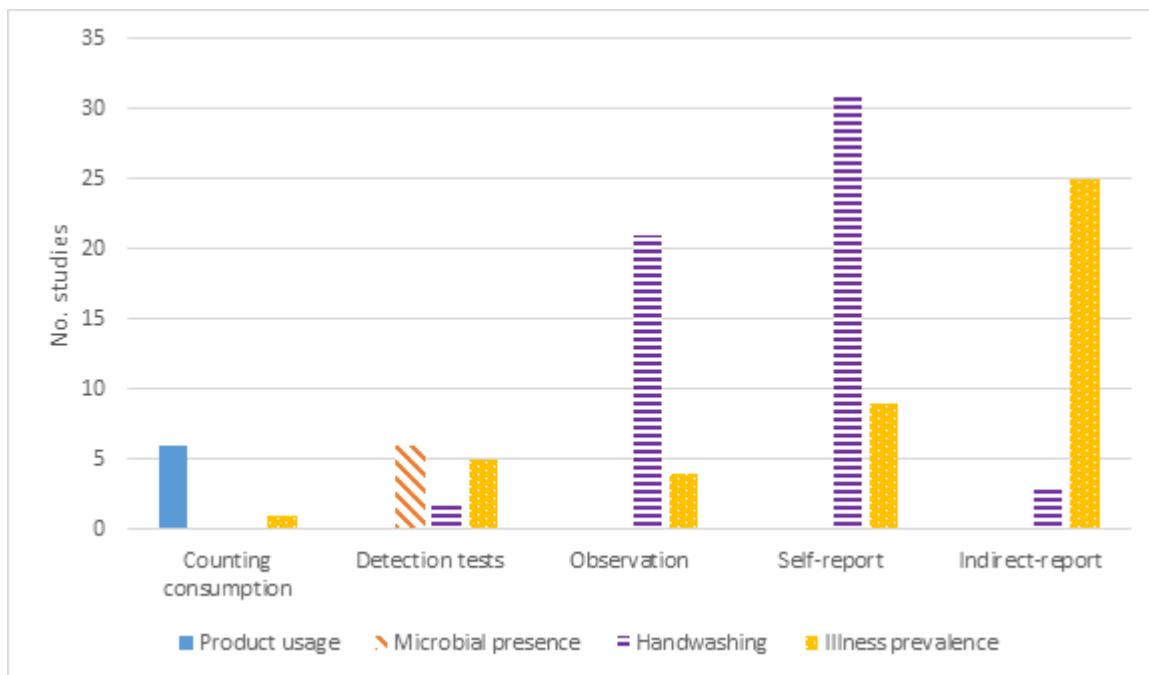


Fig 2: Use of measurement tools to evaluate handwashing in schools

Table 1: Use of indicative measures and measurement tools according to study objective

		Identify current practice, n=17	Assess intervention, n=46	Tool development, n=2
Indicative measures	Behaviour	100% (17)	78% (36)	100% (2)
	Outcome	6% (1)	67% (31)	-
	Both	6% (1)	48% (22)	-
Measurement tools	Counting consumption	-	13% (6)	-
	Detection tests	6% (1)	24% (11)	50% (1)
	Observation	24% (4)	38% (18)	50% (1)
	Self-report	82% (14)	43% (20)	-
	Indirect-report	-	54% (25)	-
No. tools	1	88% (15)	43% (20)	100% (2)
	2	12% (2)	37% (17)	-
	3	-	20% (9)	-

Table 2: Summary and considerations for use

Tool	Used to measure	Strengths	Weaknesses	When to consider usage
Counting consumption	(1) Product consumption to indicate behaviour (2) Product consumption to indicate a health outcome	(1) Can measure all handwashing events in a particular location (2) Unlikely to be influenced by Hawthorne effect	(1) Cannot distinguish between different types of event (2) Difficult to calculate (3) May require considerable access to schools	(1) In small scale intervention studies as part of a wider assessment (2) To evaluate intervention compliance when introducing a product as part of an intervention
Detection tests	(1) Occurrence, frequency and quality of handwashing to indicate a behaviour (2) Illness occurrence, illness variations and intensity of infections to indicate a health outcome	(1) Not subject to recall or reactivity	(1) Expensive with specialist equipment required (2) Time consuming (3) Analysis to some degree subjective	(1) For interventions where the objective is a reduction in a particular illness (2) Use to give more power to attributed cause and effect assumptions, if funding allows
Observation	(1) Occurrence, frequency and quality of handwashing to indicate behaviour (2) Illness prevalence to indicate a health outcome	(1) Not biased by memory (2) Highly granular (who washes hands, when and technique) (3) Can sample by child or event	(1) Time consuming. May require considerable access to schools (2) Ethical concerns e.g. toilets are private spaces (3) Over-reporting because susceptible to Hawthorne effect (4) Not easy to sample all events, particular spontaneous ones (5) Difficult to record highly granular observations	(1) Use in small scale studies if reasonable access can be negotiated, and there are sufficient researchers (2) Use in interventions to identify multiple types of effects (e.g. frequency, technique etc) (3) Use with young children who may find self-report difficult (4) If practical issues and ethical concerns can be addressed, using technology to observe children is promising
Self-report	(1) Occurrence and frequency of handwashing to indicate behaviour, (2) Illness prevalence (either absence or sickness) to indicate a health outcome	(1) Cheap and easy to administer in large numbers (2) Survey questions can cover multiple issues and different types of events (3) Can sample by child	(1) Under-reporting because handwashing is habitual (2) Over-reporting because handwashing is desirable (3) May be biased by memory, child's ability and power relationships	(1) When a large sample size is needed. (2) When handwashing is part of a wider study of health. (3) To evaluate effects and barriers on different groups of children (4) More appropriate than observations if covering sensitive issues
Indirect-report	(1) Illness prevalence (either absence or sickness) to indicate a health outcome (2) Occurrence and frequency of handwashing to indicate behaviour	(1) Considerable time saving if data already exists and is less disruptive for the school (2) Data may be available over long time periods	(1) Externally supplied data may not be detailed nor accurate	(1) Use when data already exists. (2) Use when large samples are required

Table 3: Handwashing evaluation in schools

	Age of children	Region	Study objective	Behaviour			Outcome
				Product usage	Microbial presence	Handwashing	Illness prevalence
ALBashtawy 2017	6-18	ME	CP			SR	
Al-Delaimy et al. 2014	7-12	As	I			SR	DT
Azor-Martinez et al. 2014	4-12	Eu	I				IR
Azuogu et al. 2016	12-18*	Af	CP			SR	
Bieri et al. 2013	9-10	As	I			O, SR	DT
Blanton et al. 2010	8-19	Af	I			O	IR
Bowen et al. 2007	7-8*	As	I				O, IR
Caruso et al. 2014	6-14*	Af	I			O	O
Celik & Pancoe 2012	10-11*	NA	I		DT		
Chard & Freeman 2018	8-11*	As	I			O	O, SR
Day et al. 1993	6-8	NA	I			O	IR
Dreibelbis et al. 2016	6-10*	As	I			O	
Dyer et al. 2000	5-12	NA	I				IR
Early et al. 1998	6-7, 9-10*	NA	I			O	
Freeman et al. 2012	13 (mean)	Af	I			SR	SR
Freeman et al. 2013	8-14*	Af	I				SR
Gerald et al. 2012	5-11*	NA	I	CC			CC, SR, IR
Graves et al. 2012	5-13	Af	I			O	
Grimason et al. 2014	9-11	Af	CP		DT	SR	
Grover et al. 2018	6-10*	As	I			O	
Guinan et al. 2002	5-9*	NA	I				IR
Guinan et al. 1997	11-18*	NA	CP			O	
Gyorkos et al. 2013	10	SA	I			SR	DT
Hammond et al. 2000	5-11*	NA	I				IR
Hetherington et al. 2017	14-16*	Af	I			SR	
Johansen et al. 2015	6-15	Eu	I		DT	SR	IR
Karon et al. 2017	9-11*	As	I			SR	
Krishna Kumar et al. 2016	15	As	TD			DT	
La Con et al. 2017	5-13*	Af	I			O	IR
Lau et al. 2012	4-14	NA	I			IR	IR
Lee et al. 2015	6-16	As	I			O, DT	IR

Lopez-Quintero et al. 2009	10-13	SA	CP			SR	SR
Mohammed Moussa et al. 2015	6-12	Af	I			O, SR	
Morton & Schultz 2004	5-9*	NA	I	CC			IR
Nandrup-Bus 2011	5-15	Eu	I	CC		SR	IR, SR
Nandrup-Bus 2009	5-15	Eu	I	CC		SR	IR, SR
Nicholson et al. 2014	4-11*	Eu	I				IR
O'Reilly et al. 2008	9-20	Af	I			O, SR	IR
Özyazicioğlu et al. 2011	14-18*	As	I			SR	
Parkinson et al. 2018	6-12	Af	CP			O	
Patel et al. 2012	9-13	Af	I			O, SR	IR
Peltzer & Pengpid 2014	13-15	As	CP			SR	
Pete 1986	5-18+	NA	CP			O	
Pickering et al. 2013	5-10	Af	I			O, SR	O, SR
Pickering et al. 2014	5-13*	Af	TD			O	
Priest et al. 2015	5-11	Oc	I	CC			IR
Ranasinghe et al. 2016	13-15	As / Af	CP			SR	
Randle et al. 2013	5-8	Eu	I		DT	IR	
Sandora et al. 2008	8-11*	NA	I		DT		IR
Seimetz et al. 2017	9.5 / 10.7 (mean)	Af	CP			SR	
Setyautami et al. 2012	11.5 (mean)	As	CP			SR	
Sibiya & Gumbo 2013	13-18*	Af	CP			SR	
Slekiene & Mosler 2017	6-14	Af	CP			SR	
Solehati et al. 2017	9-12*	As	I			O	
Snow et al. 2008	6-12*	NA	I			O, SR	
Stebbins et al. 2011	5-11*	NA	I				DT, IR
Susanto et al. 2016	13.17 (mean)	As	CP			SR	
Talaat et al. 2011	6-10*	Af	I				DT, IR
Tamilarasi et al. 2016	10-19	As	CP			SR	
Thakadu et al. 2018	8-16**	Af	CP			SR	
Tousman et al. 2007	6-8*	NA	I		DT	IR	IR
White et al. 2001	5-12	NA	I	CC			IR
Xuan & Hoat 2013	6-7, 9-10, 12-13*	As	CP			O, SR	

Zhang et al. 2013	6-11*	Af	I			SR	SR
Zhou et al. 2015	12-18	As	I			SR	