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When, how, and how long do adults in Germany self-reportedly wash their hands? Compliance indices based on handwashing frequency, technique, and duration from a cross-sectional representative survey

Amelia A. Mardiko, Thomas von Lengerke

Hannover Medical School, Center for Public Health and Healthcare, Department of Medical Psychology, Carl-Neuberg-Str. 1, OE 5430, 30625 Hannover, Germany

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**ABSTRACT**

**Background:** Hand hygiene is an efficacious behaviour to prevent community-associated infections. Estimates of the proportion of populations who wash their hands have indicated limited compliance. While biases of self-report items for hand hygiene, such as the tendency to overestimate one’s behaviour, represent a limitation, direct survey questions remain important. This study aims to compare indices of handwashing compliance based on single vs. combined handwashing attributes, i.e., its frequency, technique, and duration.

**Methods:** Data of a representative survey on hygiene and infection control by the German Federal Centre for Health Education were analysed. In a cross-sectional, computer-assisted telephone interview design, the resident population in Germany aged 16–85 years was surveyed in 2012. For handwashing, duration, frequency in different situations, and technique (use of soap, washing interdigital spaces, and drying hands) were self-reported. Self-reports were rated as (non-)compliant based on national recommendations and combined into single- and multi-attribute indices. Use of hand disinfectants, recall of handwashing instruction plates in public restrooms, and socio-demographics were also assessed. In total, N = 4483 persons participated (response rate: 49.7%). Data were weighted to compensate for sampling bias and analysed by cross-tabulation and multiple logistic regression. Primarily due to missing data, the analysis was confined to N = 4093 respondents (i.e., 91%).

**Results:** Among women, the proportion of those who reported to wash hands “almost always” in at least seven of nine situations was 30.8% (men: 20.3%). In contrast, 51% of men reported always using soap, drying hands, and washing interdigital spaces (women: 43.5%; p < 0.001). Compliance based on indices that included “frequency” was higher in women by 5.2% for “frequency + technique” (17.6% vs. 12.4%), and 2.5% for “frequency + duration” (13.1% vs. 10.6%) and “frequency + duration + technique” (8.8% vs. 6.3%; p < 0.02). Socio-demographic differences were most consistent regarding higher compliance among healthcare workers. Finally, especially men recalling handwashing instruction plates in public restrooms had higher compliance than those with no recall, namely, for “frequency + technique” (15.4% vs. 10.6%; OR: 1.9), all three attributes (7.6% vs. 5.3%; OR = 1.7), and “technique” (56.9% vs. 47.7%; OR = 1.6). The highest odds ratio was noted for disinfectant use among men (OR = 2.5; 12.2% vs. 4.9%).

**Discussion:** While being representative for Germany, limitations include the survey’s cross-sectionality, response rate, and the study representing the situation in 2012. Nonetheless, indices based on combined attributes allow better comparison to scarce compliance estimates for Germany based on observation. Socio-demographic differences add to existing evidence, e.g., higher compliance by healthcare workers. Finally, although reverse causation is possible, it is notable that although handwashing instruction plates in public restrooms focus on duration and technique, women recalling them reported higher frequency, and men often report hand disinfectant use, suggesting possible carry-over effects.

**Conclusion:** Self-reported handwashing compliance assessment may be improved by partitioning the behavioural domain into different attributes and using indices based on combinations of these.

* Corresponding author. Hannover Medical School, Centre for Public Health and Healthcare, Department of Medical Psychology (OE 5430), Carl-Neuberg-Str. 1, 30625 Hannover, Germany.

E-mail addresses: amelia.mardiko@gmail.com (A.A. Mardiko), lengerke.thomas@mh-hannover.de (T. von Lengerke).
1. Introduction

Hand hygiene compliance in general populations has received new prominence in the context of the current novel coronavirus pandemic (Lynch et al., 2020). It represents an efficacious public health behaviour in the prevention of community-associated infections, e.g., infections of the respiratory tract (Aiello et al., 2008; Rabie and Curtis, 2006), gastrointestinal tract (e.g., diarrhoea; Ejemot-Nwadiaro et al., 2015; Wolf et al., 2018), and skin and soft tissue (Gupta et al., 2015). In addition, estimates of the proportion of the global population who wash their hands with soap when indicated have pointed to limited compliance, e.g., handwashing after potential faecal contact in the range of 19% and 26% (Freeman et al., 2014; Wolf et al., 2019a). While these estimates were deliberately based on observed behaviour only, mainly to avoid biases of self-report measures, such as the well-documented “facets” can be distinguished for both frequency and technique. Regarding frequency, it is defined here as the different situations in which the behaviour is recommended, e.g., “after using the toilet”. Similar to professional hand hygiene (e.g., WHO, 2009), such situations are termed “indications”. Regarding technique, using water, using soap, washing interdigital spaces, and drying one’s hands are relevant facets. On this basis, the present study will compare different indices of self-reported handwashing compliance based on single and combined attributes. Compliance will be defined as correspondence with recommendations made available by the German Federal Centre for Health Education (Bundeszentrale für gesundheitliche Aufklärung) (BzgA, 2020). Thus, the study intends to contribute to the development of direct self-report measures of handwashing, and simultaneously overcome the previous focus on behavioural frequency.

Second, this study aims to describe associations of these indices of handwashing compliance with socio-demographics and self-reported recall of handwashing instruction plates in public restrooms. Such reminders have been used in Germany since the 2009 H1N1 pandemic (Meilicke et al., 2013; for details: https://www.infektionsschutz.de/mediathek/infografiken.html). Plates include information on handwashing technique and duration. In the present context, associations of recalling these plates with different self-reported hand hygiene indices may contribute to the understanding of the latter.

Moreover, the term “compliance” is used throughout this paper to denote the extent to which behaviour corresponds with recommendations regardless of whether those behaving agree with these recommendations (which would imply “adherence”). This is exclusively because the available data allows the assessment only of correspondence not agreement and represents no counter-argument to the “adherence” concept and its benefits (WHO, 2003).

In sum, it is worthwhile to further understand overestimation effects in hand hygiene self-reports and to develop alternative self-report measures by improving survey items and indices. Such improvement may merge the survey method’s practicality and efficiency with increased validity.

2. Materials and methods

2.1. Study design, setting, and participants

We used data of the BzgA’s first representative survey on hygiene and infection control conducted by the Forsa Institute for Social Research and Statistical Analysis from June–August 2012 as a cross-sectional, computer-assisted telephone interview survey of the adult population in Germany aged 16–85 years (BzgA, 2013). It used a dual-frame multi-stage random sampling design based on the then current selection framework by the Working Group of German Market and Social Research Institutes (ADM Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute, 1999) to include individuals reachable by cellular mobile telephone only. Within households reached via fixed-line, the person included was selected by the last birthday method. The sample was augmented to include a sub-sample of women pregnant at the time of the survey. This group is not addressed in the present analysis due to its aim to provide estimates for the general population, and both women and men, thus, this feature is taken into account in data weighting only (see below). The realized net sample consisted of N = 4483 respondents, including N = 3730 from the fixed-line and N = 753 from the mobile sampling frame. The survey response rates were 53.2% for the former and 38.7% for the latter, resulting in an overall rate of 49.7%. In statistical analyses, data were weighted to compensate for sampling biases inherent both in the differential selection probabilities for the two sampling frames and the oversampling of pregnant women. The data are publicly available online at the Data Archive for the Social Sciences of the GESIS Leibniz Institute for the Social Sciences (BzgA,
2.2. Measures: survey items and compliance indices

In the following sections, authors’ translations of the original German survey items into English are provided. The original items are available from the corresponding author and in BZgA (2015). For all items, the answer categories “I don’t know” and “Not specified” were not presented in the interview but coded either if the respondent either gave a respective answer by him- or herself, or responded in a way that after could, after clarification, be fitted validly into one of the categories by the interviewer.

2.2.1. Handwashing compliance

The attribute frequency was operationalized for nine indications (facets) using the following item: How often do you wash your hands in each of the following situations, i.e., never, seldom, mostly, or almost always? Indications were “before eating”, “after touching animals”, “after shaking hands”, “before preparing food”, “when coming home from outside”, “after using the toilet”, “after blowing one’s nose or coughing in one’s hand”, “after being with someone who had the flu, a gastrointestinal disease, or a similarly contagious disease”, and “before visiting a person who is weak because of ill-health”. In the first step of the indexing process, each of the nine facets was dichotomized so that “almost always” was coded as “compliant”. Then, the frequency of the code “compliant” was summed across the nine new variables, yielding a new variable for the number of indications with compliant handwashing frequency (range: 0–9). Values of this variable >0 were trichotomized into approximately equal groups, yielding groups with 1–3, 4–6, or 7–9 indications with compliant handwashing frequency. Following a practice by Wolf et al. (2019b), these choices were made subjectively “… as a simplified approach and in order to get a good distribution of scores” (Wolf et al., 2019b, p. 272).

For technique, three facets were distinguished. First, use of soap or wash lotion was assessed by the following item: If possible, do you always use soap or wash lotion for handwashing, or do you usually wash your hands just with clear water without soap? Possible answers included “If possible always with soap or wash lotion”, “Mostly only with clear water”, or “Differently every time”. The inclusion of interdigital spaces in handwashing was operationalized as follows: Do you wash your hands between

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Fig. 1. Terminology employed for structuring and operationalizing general population hand hygiene as a behavioural domain.

Notes: 1Hand disinfection is used to denote hand rubbing in terms of using an alcohol-containing preparation designed for application to the hands. In the present survey, facets are represented by individual items. Attributes and facets for which data were unavailable in this study are indicated in italics.
the fingers? “almost always”, ‘mostly’, ‘seldom’, or ‘never’. For hand drying, the item Do you dry your hands carefully after handwashing? was used with the same answer categories as that for interdigital spaces. The first indexing step was to dichotomize these variables by coding “If possible always with soap or wash lotion” and “almost always” as compliant. Then, the number of times the code “compliant” occurred was summed across the three new variables. This yielded a new variable (range: 0–3) representing the number of technical facets self-reportedly complied with.

The attribute duration was operationalized by the item According to your estimation, how long does it usually take to wash your hands: “Less than 10 s”, “10 s to under 20 s”, or “20 s or more”? According to recommendations, 20 s or more was coded as “compliant”.

For indices combining either pairs of or all three attributes (frequency, technique, and duration), the number of “compliant”-ratings was summed across each pair, resulting in variables with three values (0–2), and across all three attributes, resulting in a variable with four values (0–3). For some analyses, these variables were re-coded into high compliance (highest value) and groups of lower compliance.

2.2.2. Hand disinfection behaviour

The item for use of hand disinfectants (not designated as “compliance” in this study because no recommendations exist for the public in Germany) read as follows: Do you use disinfectants to sanitise your hands in your daily routine? Do you use it “regularly”, “only in specific situations”, or “never”? Thus, for hand disinfection, only overall frequency is examined.

2.2.3. Self-reported recall of handwashing instruction plates in public restrooms

This item read as follows: In some public toilets, there is an instruction plate on the top of the mirror above the sink explaining step by step what to pay attention to when washing one’s hands. Have you seen such an instruction plate before or have you not seen such a plate before? As answer categories, “seen before” and “never seen such a plate” were provided.

2.2.4. Socio-demographics

Sex and age were assessed by single items, the latter being inferred by the difference between the survey date and the birthday reported by respondent. Items assessing educational background (formal school education), current employment status, work in healthcare, migration background (“migration background” was coded if the country of birth of both the respondent and his parents was not Germany and/or their citizenship was not German), and number of children living in the respondent’s household can be found in Table S1 (available in the supplementary material). Indexing algorithms followed socio-demographic standards by the German Federal Statistical Office (Hoffmeyer-Zlotnik et al., 2010) and are available upon request from the corresponding author.

2.3. Statistical analysis

Analyses were conducted separately for women and men due to gender differences in handwashing frequency (women > men) (White et al., 2020). As noted before, data were weighted to compensate for sampling biases (fixed-line vs. cellular mobile, and oversampling of pregnant women) (BZgA, 2013). In addition to cross-tabulations, in which 95% confidence intervals were calculated with OpenEpi v3.01 (Dean and S ore, 2013), multiple logistic regression analyses were conducted with IBM® SPSS® Statistics v26. All tests were two-sided. Statistical significance was defined as a p-value less than 0.05, and p-values greater than 0.001 are reported with exact figures to three decimal places.

3. Results

3.1. Sample description

N = 2 respondents (0.04%) who indicated never washing their hands in daily practice and N = 39 (0.9%) with a missing value in this variable were excluded. Additionally, N = 325 (7.2%) with missing data in the variables sex, age or handwashing attributes (frequency, technique, and duration) were excluded. Thus, valid data were available from 4117 participants. After weighting the data as described above (see Study design and sample-section), the analytical sample was N = 4093.

Stratified for women and men, Table 1 shows the socio-demographic attributes of these respondents. Regarding age, women were on average 1.7 years older than men. Among both sexes, approximately 40% reported secondary general school as their highest degree. While about half of the women were currently working, this was around two-thirds for men. In contrast, the proportion of respondents with any type of professional activity in healthcare was higher in women (14.2%) than in men (5.1%); when related to those in employment, training, education or material or parental leave, these rates – not shown here – were 23.7% and 7.4%, respectively. Rates of respondents with any migration background (see Table S1 for details) were generally similar among women and men; this cross-tabulation was the only one with an insignificant Chi² statistic (p = 0.243; all others at least p ≤ 0.025). Approximately 28.6% of the women lived in the same household with at least one child under 16 years, while 21.7% among men did. Finally, 40.3% of the women reported to have seen a handwashing instruction plate in public restrooms at least once (men: 35.5%).

| Table 1 | Sample description1. |
|---------|---------------------|
|         | Women               | Men            |
| N   | %   |          | N   | %   |
| TOTAL  |      |          |      |      |
| Age
| 16–29 years | 404 19.1 | 421 21.3 |
| 30–44 years | 509 24.1 | 505 25.5 |
| 45–59 years | 578 27.4 | 564 28.4 |
| 60–85 years | 619 29.3 | 492 24.8 |
| Mean (SD) | 48.2 (17.9) | 46.5 (17.3) |
| Educational background
| low (secondary general school) | 848 40.2 | 831 42.2 |
| medium (intermediate school) | 724 34.5 | 509 25.8 |
| high (upper secondary school) | 527 25.1 | 629 32.0 |
| Currently working
| Yes | 1076 52.4 | 1264 65.0 |
| No  | 978 47.6  | 680 35.0 |
| Healthcare worker
| Yes | 300 14.2 | 100 5.1 |
| No  | 1811 85.8 | 1882 94.9 |
| Migration background
| Yes | 438 20.8 | 383 19.3 |
| No  | 1669 79.2 | 1599 80.7 |
| Children in the household
| Yes | 601 28.6 | 428 21.7 |
| No  | 1503 71.4 | 1543 78.3 |
| Recalling having seen handwashing instruction plates in public restrooms
| At least once | 848 40.3 | 700 35.5 |
| No  | 1255 59.7 | 1274 64.5 |

Notes: 1 Differences to sample description in BZgA (2013) due to differences in exclusion criteria applied (for details, see 3.1. Sample description) 2 Row-% (all other rates: column-%, whereby all sub-samples not adding up to total are due to missing values).
3.2. Associations of handwashing compliance indices based on single vs. combined attributes, and use of hand disinfectants, with socio-demographics and self-reported recall of handwashing instruction plates in public restrooms

As Table 3 further indicates, compliance rates in all indices based on single or combined attributes, i.e., frequency and technique facets, and use of hand disinfectants, while Table 2 shows the distributions of the different indices defined by single and combined attributes, i.e., frequency, technique, and duration. As Table 3 shows, 30.8% among women and 20.3% among men reported washing their hands in seven or more of the indications. In contrast, for handwashing technique and duration, higher compliance rates were reported by men: 51% reported to always use soap, dry their hands, and wash interdigital spaces (women: 43.5%). Regarding duration, i.e. washing one’s hands 20 s or more, the difference was less pronounced.

As Table 3 indicates, compliance rates in all indices based on single attributes were lowest both in women and men. Finally, more women pertained to frequency and duration as single attributes and the combination facet. Expectably, compliance based on the combination of all three attributes was insignificantly. The two oldest groups among men tended to report higher compliance due to non-existent recommendations. As Table 3 shows, 30.8% among women and 20.3% among men reported washing their hands in seven or more of the indications. In contrast, for handwashing technique and duration, higher compliance rates were reported by men: 51% reported to always use soap, dry their hands, and wash interdigital spaces (women: 43.5%). Regarding duration, i.e. washing one’s hands 20 s or more, the difference was less pronounced.

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the difference between respondents working in healthcare vs. not. Regarding handwashing compliance, ORs ranged from 1.8 (frequency as well as frequency and technique combined) to 2.5 (technique and duration combined) among women and from 1.5 (technique) to 3.0 (combination of frequency and duration) among men, all indicating higher compliance among healthcare workers (Table 5). Differences in regular use of hand disinfectants were even more pronounced. Comparing respondents currently working vs. not, regardless of healthcare, significant differences indicated lower handwashing compliance in those working for frequency (women and men), duration (men), and combinations of frequency and technique (women), and frequency and duration (men). Significantly higher rates in those working pertained to technique (men) and the use of hand disinfectants (women).

Respondents with a migration background reported a higher frequency of handwashing both in women and men, albeit on different levels. Correspondingly, higher rates were found for the combination of frequency and technique as well as frequency and duration (men only), while differences for frequency, technique and duration combined were smaller and insignificant. This trend also held for regular use of hand disinfection.

Reported compliance rates by and large did not significantly co-vary by children living in the household vs. not. Actually, the only significant difference among both women and men was found for handwashing frequency in terms of lower compliance in respondents from a household with children. Among men, a similar assertion held for handwashing duration.

Finally, regarding recall of handwashing instruction plates in public restrooms, ORs for all hand hygiene parameters were greater than 1. For compliance with technique and the combination of frequency and technique among women as well as duration and frequency and duration combined among men, no statistically significant associations were observed (the OR for frequency among men was significant, but reflected uniform compliance rates of 20.2%). The highest OR was determined for use of hand disinfectants among men (2.5; see Table 5), reflecting a bi-variate difference between 12.2% and 4.9% (Table 4). Regarding handwashing, the highest ORs also pertained to men. For women, the highest OR was found for frequency (single attribute).

### 4. Discussion

The results of the present analysis can be summarized as follows. Related to the paper’s first aim, self-reported compliance rates varied between single-digits and near ubiquity for single facets of handwashing frequency, and between two-thirds to nine-tenths for single technical facets. In contrast, rates based on combinations of facets approximately varied between two-to three-tenths for frequency, and four-to five-tenths for technique. Regarding combinations of attributes, i.e., indices based on more than one of frequency, technique, and duration, compliance rates were even lower, varying from one-to two-tenths given two attributes, and in single-digit range for the index based on all attributes.

Regarding the second aim, two clusters of results stand out. First, among socio-demographics, the trends to higher levels of handwashing in the sub-groups with higher age and lower formal education level add to the inconsistent or mixed results recently determined for these associations (White et al., 2020). This may at least partly reflect associations with social desirability reported among German adults, which tends to increase with age, and to be lower given lower education (Haberecht et al., 2015). The higher compliance rates found for respondents with a migration background are consistent with White et al. (2020). Additionally, the positive association of working in healthcare with handwashing compliance was consistent, i.e., found for indices based on single or combined attributes, and was even more strongly linked to hand disinfectants use. Second, the results for recall of handwashing instructions showed noteworthy patterns. Associations with handwashing compliance were generally stronger among men. Additionally, among single attributes, in addition to frequency, technique among men and to a lesser degree duration among women was associated with recall. This notion was also reflected in the indices based on combined attributes. On the other hand, among men, the strongest association was recall. This notion was also reflected in the indices based on combined attributes.

Finally, regarding recall of handwashing instruction plates in public restrooms, ORs for all hand hygiene parameters were greater than 1. For compliance with technique and the combination of frequency and technique among women as well as duration and frequency and duration combined among men, no statistically significant associations were observed (the OR for frequency among men was significant, but reflected uniform compliance rates of 20.2%). The highest OR was determined for use of hand disinfectants among men (2.5; see Table 5), reflecting a bi-variate difference between 12.2% and 4.9% (Table 4). Regarding handwashing, the highest ORs also pertained to men. For women, the highest OR was found for frequency (single attribute).

### Table 3

Distributions of single and combined attributes of self-reported handwashing behavior in German adults.

| SINGLE ATTRIBUTES | Women | Men |
|-------------------|-------|-----|
| Frequency\(^{a}\) | 650   | 403 |
| Technique\(^{b}\) | 806   | 667 |
| Duration\(^{a}\)  | 287   | 245 |
| Combined attributes | 372   | 269 |

| Frequency and technique\(^{c}\) | 824   | 915 |
| Technique and duration\(^{c}\) | 814   | 1021 |
| Combined attributes | 890   | 1045 |

| Frequency and duration\(^{d}\) | 121   | 209 |
| Technique and duration\(^{d}\) | 809   | 1045 |

### Notes:

1. For details, see **2.2. Measures: items and indices** and Table S1.
2. Categories formatted in **bold format** considered as self-reported compliance.

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| WOMEN | Handwashing compliance based on single attributes | Handwashing compliance based on combined attributes | Regular use of hand disinfectants |
|-------|-----------------------------------------------|-----------------------------------------------|---------------------------------|
|       | Frequency + Technique | Frequency + Duration | Technique + Duration | Frequency + Technique + Duration | N % | 95%-CI  | N % | 95%-CI  | N % | 95%-CI  | N % | 95%-CI  |
| Age   |                                |                                |                           |                                |     |          |     |          |     |          |     |          |
| 60-85 years |                                |                                |                           |                                | 209 | 33.8     | 30.2-37.6 | 273 | 44.1     | 40.2-48.0 | 212 | 34.2     | 30.6-38.1 |     |          |     |          |
| 45-59 years |                                |                                |                           |                                | 162 | 28.0     | 25.1-31.8 | 271 | 46.8     | 42.8-50.1 | 208 | 36.0     | 32.2-40.0 |     |          |     |          |
| 30-44 years |                                |                                |                           |                                | 149 | 29.3     | 25.5-33.4 | 211 | 41.5     | 37.3-45.8 | 174 | 34.1     | 30.1-38.3 |     |          |     |          |
| 16-29 years |                                |                                |                           |                                | 130 | 32.2     | 27.8-36.9 | 163 | 40.3     | 35.6-45.2 | 121 | 30.0     | 25.5-34.6 |     |          |     |          |
| Educational background | low (secondary general school) |                                |                           |                                | 233 | 39.3     | 36.0-42.6 | 357 | 42.1     | 38.8-45.5 | 287 | 33.8     | 30.7-37.1 |     |          |     |          |
|       | medium (intermediate school) |                                |                           |                                | 182 | 25.1     | 22.1-28.4 | 351 | 48.5     | 44.9-52.1 | 254 | 35.1     | 31.2-38.6 |     |          |     |          |
|       | high (upper secondary school) |                                |                           |                                | 132 | 25.0     | 21.5-28.9 | 204 | 38.7     | 34.7-42.9  | 168 | 31.9     | 28.0-36.0 |     |          |     |          |
|       | Currently working |                                |                           |                                | Yes | 284 | 26.4 | 23.9-29.1 | 473 | 44.0 | 41.0-46.9 | 374 | 34.8 | 32.0-37.7 |     |          |     |          |
|       |                                |                                |                           |                                | No  | 347 | 35.5 | 32.5-38.5 | 423 | 43.3 | 40.8-46.4 | 326 | 33.3 | 30.5-36.4 |     |          |     |          |
| Healthcare worker | Yes |                                |                           |                                | 106 | 35.3 | 30.1-40.9 | 172 | 57.3 | 51.2-62.8 | 145 | 48.3 | 42.3-54.0 |     |          |     |          |
|       | No |                                |                           |                                | 545 | 30.1 | 28.0-32.2 | 745 | 41.1 | 38.9-43.9 | 570 | 31.5 | 29.4-33.7 |     |          |     |          |
| Migration background | Yes |                                |                           |                                | 193 | 44.1 | 39.5-48.7 | 193 | 44.1 | 39.5-48.7 | 123 | 57.8 | 52.0-63.7 |     |          |     |          |
|       | No |                                |                           |                                | 457 | 27.4 | 25.0-30.0 | 724 | 43.4 | 41.0-45.8 | 592 | 35.5 | 33.2-37.8 |     |          |     |          |
| Children in the household | Yes |                                |                           |                                | 171 | 28.4 | 25.0-32.1 | 254 | 42.3 | 38.4-46.3 | 197 | 32.7 | 29.1-36.6 |     |          |     |          |
|       | No |                                |                           |                                | 476 | 31.7 | 29.4-34.1 | 660 | 45.9 | 43.4-48.4 | 265 | 30.6 | 27.3-34.0 |     |          |     |          |
| Recall of handwashing instruction plates in public restrooms | At least once |                                |                           |                                | 310 | 36.6 | 33.4-40.0 | 380 | 44.8 | 41.5-48.2 | 315 | 37.1 | 34.0-40.5 |     |          |     |          |
|       | No |                                |                           |                                | 337 | 26.8 | 24.5-29.4 | 533 | 42.5 | 39.7-45.2 | 399 | 31.8 | 29.3-34.4 |     |          |     |          |
| MEN | Handwashing compliance based on single attributes | Handwashing compliance based on combined attributes | Regular use of hand disinfectants |
|       | Frequency + Technique | Frequency + Duration | Technique + Duration | Frequency + Technique + Duration | N % | 95%-CI | N % | 95%-CI | N % | 95%-CI | N % | 95%-CI |
| Age   |                                |                                |                           |                                |     |          |     |          |     |          |     |          |
| 60-85 years |                                |                                |                           |                                | 122 | 24.7 | 21.1-28.7 | 263 | 53.5 | 49.0-57.8 | 222 | 45.1 | 40.8-49.5 |     |          |     |          |
| 45-59 years |                                |                                |                           |                                | 141 | 25.0 | 21.6-28.7 | 266 | 46.2 | 42.1-50.3 | 260 | 46.1 | 42.0-50.2 |     |          |     |          |
| 30-44 years |                                |                                |                           |                                | 77 | 15.3 | 12.4-18.7 | 268 | 53.1 | 48.7-57.4 | 153 | 30.3 | 26.5-34.4 |     |          |     |          |
| 16-29 years |                                |                                |                           |                                | 63 | 15.0 | 11.8-18.6 | 220 | 52.1 | 47.4-57.9 | 108 | 25.7 | 21.7-29.9 |     |          |     |          |
| Educational background | low (secondary general school) |                                |                           |                                | 190 | 22.9 | 20.1-25.8 | 469 | 56.4 | 53.1-59.8 | 350 | 42.1 | 38.8-45.5 |     |          |     |          |
|       | medium (intermediate school) |                                |                           |                                | 117 | 23.0 | 19.5-26.8 | 260 | 51.1 | 46.5-55.4 | 196 | 38.5 | 34.4-42.8 |     |          |     |          |
|       | high (upper secondary school) |                                |                           |                                | 92 | 14.6 | 12.1-17.6 | 275 | 43.7 | 39.9-47.6 | 192 | 30.5 | 27.1-34.2 |     |          |     |          |
|       | Currently working |                                |                           |                                | Yes | 228 | 18.9 | 16.0-20.3 | 673 | 53.2 | 50.1-56.0 | 448 | 35.4 | 32.9-38.1 |     |          |     |          |
|       | No |                                |                           |                                | 164 | 24.1 | 21.0-27.4 | 332 | 48.8 | 45.0-52.5 | 288 | 42.4 | 38.6-46.0 |     |          |     |          |

(continued on next page)
Several limitations also exist. First, the overall survey response rate was 49.7% (calculation based on BZgA, 2013, 2015) and even lower in the cellular mobile sampling frame (38.7%). While such response rates are common in population surveys in Europe (Beuïens et al., 2018), the present results may have been affected by selection biases, especially as the survey was on, among other things, hygiene behaviour, which may represent a potentially sensitive topic for some. Additionally, the lower rate in the mobile sampling frame may predominantly have affected younger adults. Both may limit the generalizability (external validity) of the results to the German population as a whole. Second, not all facets of handwashing technique were covered. On the one hand, the use of clean and running water before and after applying soap or wash lotion should also be assessed. On the other hand, participants were asked if they washed their hands between the fingers, i.e., interdigital spaces, while recommendations suggest washing all parts of the hands (BZgA, 2020). Third, both the frequency and the technical facets were weighted equally, i.e., the value 1 was added to the index for every compliant facet. While this admittedly is a simplifying procedure, we are not aware of data quantitatively suggesting other weights, e.g., in relation to effectiveness. Fourth, the present data reflect the situation in Germany in 2012, and analyses should be replicated with more recent data (BZgA, 2018), especially to elucidate the effects of more recent epidemics, i.e., influenza in 2017/18 and the COVID-19 pandemic in 2020. Fifth, the survey was cross-sectional, so reverse causality cannot be ruled out. This especially holds for the associations of self-reported handwashing with the recall of handwashing instruction plates in public restrooms. Thus, it is entirely possible that men who compliantly wash their hands (or at least self-report this) are more prone to remember these prompts, not the other way around. However, the associations found show that self-reported compliance and recollection are not completely unrelated, which would have suggested complete irrelevance of these prompts. Finally, and in relation to the former limitation, the present data are self-reports of hand hygiene. Thus, on one hand, they obviously do not claim to correspond to assessments based on observation. On the other, possible reporting biases in terms of differential reporting tendencies have to be taken into account. E.g., in contrast to others (White et al., 2020), we did not find women to be more likely to wash their hands with soap. This may be due to men’s stronger propensity to falsely self-report preventive behaviours, as shown for, e.g., colorectal cancer screening use (Griffin et al., 2009). Thus, feedback to men of their over-estimation may even be more important than that for women.

Keeping these limitations in mind, the main impetus of the present paper was to provide an in-depth analysis of handwashing compliance based on a multitude of attributes and facets of handwashing were analysed. Additionally, studies on handwashing behaviour and its determinants from high-income countries are still more infrequent than those from middle- or low-income countries (White et al., 2020). Using data from Germany, this study adds to the global current state of research.
| WOMEN | Handwashing compliance based on single attributes | Handwashing compliance based on combined attributes | Regular use of hand disinfectants |
|-------|--------------------------------------------------|-----------------------------------------------------|----------------------------------|
|       | Frequency | Technique | Duration | Frequency | Technique | Duration | Frequency | Technique | Duration | OR | 95% CI | p     | OR | 95% CI | p     |
|       | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        |     |         |       |     |         |       |
| Age   |                                                   |                                                   |                                   |                                                   |
| 60–85 years | 1.2 | 0.9–1.7 | − | 1.4 | 1.0–1.9 | − | 1.4 | 1.0–2.0 | − | 1.8 | 1.2–2.8 | − | 1.4 | 0.9–2.2 | − | 1.6 | 1.1–2.3 | − | 2.1 | 1.2–3.6 | − | 0.3 | 0.2–0.6 | < 0.001 |
| 45–59 years | 1.1 | 0.8–1.5 | − | 1.4 | 1.1–1.9 | − | 1.5 | 1.1–2.0 | − | 1.5 | 1.0–2.2 | − | 1.1 | 0.7–1.7 | − | 1.3 | 0.9–1.9 | − | 1.5 | 0.9–2.5 | − | 0.6 | 0.4–0.8 | 0.003 |
| 30–44 years | 1.3 | 0.9–1.8 | − | 1.1 | 0.8–1.5 | − | 1.4 | 1.0–1.9 | − | 1.2 | 0.8–1.9 | − | 1.5 | 1.0–2.3 | − | 1.4 | 0.9–2.0 | − | 1.5 | 0.9–2.5 | − | 0.5 | 0.3–0.8 | < 0.001 |
| 16–29 years | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Educational background |                                                   |                                                   |                                   |                                                   |
| low (secondary general school) | 2.0 | 1.5–2.6 | < 0.001 | 1.1 | 0.9–1.4 | − | 1.2 | 0.9–1.5 | − | 1.3 | 1.0–1.8 | − | 1.6 | 1.1–2.3 | − | 1.2 | 0.9–1.6 | − | 1.1 | 0.7–1.6 | 1.9 | 1.3–2.8 | < 0.001 |
| medium (intermediate school) | 1.1 | 0.8–1.4 | 0.528 | 1.4 | 1.1–1.8 | − | 1.2 | 0.9–1.5 | − | 1.3 | 0.9–1.8 | − | 1.3 | 0.9–1.9 | − | 1.4 | 1.0–1.9 | − | 1.3 | 0.8–1.9 | 1.8 | 1.2–2.6 | < 0.001 |
| high (upper secondary school) | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Currently working |                                                   |                                                   |                                   |                                                   |
| Yes | 0.7 | 0.5–0.8 | − | 0.9 | 0.7–1.1 | − | 0.9 | 0.7–1.1 | − | 0.7 | 0.5–1.0 | − | 0.9 | 0.6–1.2 | − | 0.8 | 0.6–1.1 | − | 0.8 | 0.6–1.2 | 1.8 | 1.3–2.7 | < 0.001 |
| No | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Healthcare worker |                                                   |                                                   |                                   |                                                   |
| Yes | 1.8 | 1.3–2.3 | < 0.001 | 2.1 | 1.6–2.7 | < 0.001 | 2.2 | 1.7–2.9 | < 0.001 | 1.8 | 1.3–2.5 | < 0.001 | 2.4 | 1.7–3.4 | < 0.001 | 2.5 | 1.9–3.4 | < 0.001 | 2.1 | 1.4–3.1 | 4.2 | 3.1–5.7 | < 0.001 |
| No | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Migration background |                                                   |                                                   |                                   |                                                   |
| Yes | 2.1 | 1.7–2.7 | < 0.001 | 1.1 | 0.9–1.4 | − | 0.7 | 0.6–0.9 | − | 1.9 | 1.4–2.4 | − | 1.3 | 0.9–1.7 | − | 0.7 | 0.5–0.9 | − | 1.4 | 1.0–2.0 | 1.3 | 1.0–1.8 | 0.093 |
| No | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Children in the household |                                                   |                                                   |                                   |                                                   |
| Yes | 0.7 | 0.6–0.9 | − | 1.0 | 0.8–1.3 | − | 0.9 | 0.7–1.2 | − | 1.1 | 0.8–1.5 | − | 0.8 | 0.6–1.1 | − | 1.1 | 0.8–1.4 | − | 0.9 | 0.6–1.4 | 0.8 | 0.5–1.1 | 0.110 |
| No | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| Recall of handwashing instruction plates in public restrooms |                                                   |                                                   |                                   |                                                   |
| At least once | 1.7 | 1.4–2.1 | < 0.001 | 1.2 | 1.0–1.4 | − | 1.4 | 1.1–1.7 | − | 1.2 | 0.9–1.6 | − | 1.5 | 1.2–2.0 | − | 1.4 | 1.1–1.8 | − | 1.5 | 1.1–2.1 | 1.4 | 1.1–1.9 | 0.016 |
| Never | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |
| MEN | Handwashing compliance based on single attributes | Handwashing compliance based on combined attributes | Regular use of hand disinfectants |
|       | Frequency | Technique | Duration | Frequency | Technique | Duration | Frequency | Technique | Duration | OR | 95% CI | p     | OR | 95% CI | p     |
|       | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        | OR 95% CI | p        |     |         |       |     |         |       |
| Age   |                                                   |                                                   |                                   |                                                   |
| 60–85 years | 1.7 | 1.2–2.5 | − | 1.2 | 0.9–1.7 | − | 2.2 | 1.6–3.0 | < 0.007 | 1.7 | 1.1–2.7 | − | 1.4 | 0.8–2.2 | < 0.001 | 1.5 | 1.5–3.2 | < 0.001 | 1.5 | 0.8–2.6 | 1.9 | 1.0–3.5 | 0.053 |
| 45–59 years | 2.0 | 1.4–2.9 | < 0.001 | 0.7 | 0.5–0.9 | − | 2.4 | 1.8–3.2 | − 0.001 | 1.0 | 0.7–1.5 | − | 2.0 | 1.3–3.1 | − 0.001 | 1.4 | 1.0–2.1 | − 0.003 | 0.8 | 0.5–1.3 | 1.0 | 0.6–1.7 | 0.903 |
| 30–44 years | 1.1 | 0.8–1.7 | − 0.534 | 1.0 | 0.7–1.3 | − 0.737 | 1.2 | 0.9–1.7 | − 0.209 | 0.6 | 0.4–0.9 | − 0.020 | 0.6 | 0.3–1.1 | − 0.090 | 1.4 | 0.9–2.0 | − 0.108 | 0.3 | 0.1–0.6 | < 1.0 | 0.6–1.8 | 0.906 |
| 16–29 years | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. | ref. |

(continued on next page)
| WOMEN          | Handwashing compliance based on single attributes | Handwashing compliance based on combined attributes | Regular use of hand disinfectants |
|----------------|---------------------------------------------------|---------------------------------------------------|----------------------------------|
|                | Frequency                                         | Technique                                         | Duration                         | Frequency + Technique | Frequency + Duration | Technique + Duration | Frequency + Technique + Duration | OR  95%-CI | p     | OR  95%-CI | p     | OR  95%-CI | p     | OR  95%-CI | p     |
|                | OR  95%-CI | p                                             | OR  95%-CI | p                                             | OR  95%-CI | p                                             | OR  95%-CI | p                                             | OR  95%-CI | p                                             |
| Educational background |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| low (secondary general school) | 1.7 1.3-2.2 | 0.001 0.01 | 1.7 1.4-2.2 | 0.001 0.01 | 1.8 1.3-2.6 | 0.001 0.01 | 1.6 1.1-2.3 | 0.013 0.003 | 1.5 1.2-2.0 | 0.002 0.02 | 1.2 0.7-1.9 | 0.527 0.074 | 1.0 0.6-1.6 | 0.975 0.042 |                     |
| medium (intermediate school) | 1.9 1.4-2.6 | 0.001 0.01 | 1.9 1.1-1.9 | 0.003 0.003 | 2.0 1.4-2.9 | 0.001 0.01 | 1.7 1.1-2.6 | 0.010 0.004 | 1.5 1.1-2.0 | 0.010 0.01 | 1.6 1.0-2.6 | 0.069 0.042 | 1.6 1.0-2.5 | 0.81 0.068 |                     |
| high (upper secondary school) | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |
| Currently working |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| Yes | 0.7 0.5-1.0 | 0.023 0.02 | 0.7 0.6-1.0 | 0.025 0.025 | 1.2 0.8-1.7 | 0.422 0.002 | 0.5 0.4-0.8 | 0.001 0.001 | 1.1 0.8-1.6 | 0.407 0.34 | 1.5 0.9-2.5 | 0.113 0.076 | 1.6 0.9-2.8 | 0.08 0.068 |                     |
| No | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |
| Healthcare worker |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| Yes | 2.0 1.2-3.3 | 0.005 0.01 | 2.1 1.4-3.3 | 0.001 0.001 | 2.0 1.1-3.5 | 0.018 0.004 | 3.0 1.7-5.5 | 0.001 0.001 | 1.6 1.0-2.6 | 0.056 0.02 | 1.8 0.9-3.9 | 0.107 0.005 | 7.9 4.7-13.2 | 0.001 0.001 |                     |
| No | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |
| Migration background |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| Yes | 1.8 1.3-2.3 | 0.001 0.01 | 1.1 0.9-1.4 | 0.466 0.002 | 1.7 1.2-2.3 | 0.004 0.001 | 1.7 1.2-2.4 | 0.006 0.001 | 0.8 0.6-1.1 | 0.111 0.02 | 1.3 0.8-2.2 | 0.235 0.065 | 1.2 0.7-1.9 | 0.460 0.077 |                     |
| No | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |
| Children in the household |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| Yes | 0.7 0.5-1.0 | 0.049 0.01 | 1.2 1.0-1.6 | 0.083 0.003 | 1.0 0.7-1.5 | 0.849 0.004 | 0.7 0.4-1.1 | 0.080 0.004 | 1.1 0.8-1.5 | 0.544 0.02 | 0.9 0.5-1.5 | 0.632 0.005 | 1.5 1.0-2.3 | 0.077 0.008 |                     |
| No | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |
| Recall of handwashing instruction plates in public restrooms |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |
| At least once | 1.2 1.0-1.7 | 0.038 0.001 | 1.1 0.9-1.4 | 0.272 0.001 | 1.9 1.4-2.5 | 0.001 0.001 | 1.2 0.9-1.7 | 0.300 0.001 | 1.5 1.2-1.9 | 0.001 0.001 | 1.7 1.2-2.5 | 0.008 0.001 | 2.5 1.7-3.6 | 0.001 0.001 |                     |
| Never | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. | ref. ref. |                     |

Note: OR: odds ratio; CI: confidence interval; all estimates are from the multiple logistic regression model for each respective behavioural indicator, which included all predictors listed (i.e. age, educational background, current work status, working in healthcare, migration background, children in the household, and recall of handwashing instruction plates in public restrooms).
e., 1+(84.1-48.7)/48.7)). With all bidden caution, this may be considered as a speculative but thought-provoking impulse in terms of possibilities to develop algorithms for correcting self-reported handwashing based on observed compliance. Such an endeavour may borrow from related efforts in which self-reported body mass indices (BMI) are multiplied with correction factors empirically derived by comparison with measured BMI to produce corrected body mass classification (see e.g., Drieskens et al., 2018). Unfortunately, no pertinent data are available for Germany’s general population using the day reconstruction or the script-based covert recall method. In any case, self-reported compliance estimates based on combined attributes, such as those reported here, may be used in handwashing promotion campaigns to provide more concise feedback on the behaviour of the population, i.e., based not only on frequency, but duration and technique as well. This may sensitize target groups in regard to discrepancies between subjective estimates of their own handwashing habits and the “objective” reality.

Finally, the analyses of determinants of self-reported hand hygiene behaviour, i.e., – following recent nomenclature (White et al., 2020) – especially characteristics (i.e., socio-demographics) and (as one feature of the social environment) recall of handwashing instructions plates in public restrooms, produced results that were by and large consistent with findings of earlier studies (White et al., 2020). Additionally, it seems fair to say that the associations between socio-demographics and the different handwashing indices, i.e., based on single vs. combined attributes, revealed a number of notable variations (e.g., higher compliance with technical facets of handwashing among men and with indications but not duration and technique among respondents with a migration background). At the same time, they were not dissimilar overall to an extent that would clearly contradict earlier findings. Regarding handwashing instruction plates in public toilets, it may be a significant finding that although these reminders focus on duration and technique of handwashing, women recalling them reported higher compliance regarding frequency. Among men, this notion especially held for regular use of hand disinfectants. Thus, further studies may be worthwhile to examine whether information on specific attributes of handwashing carries over to other attributes or hand hygiene behaviours in educational campaigns or whether our finding merely reflects reverse causation (i.e., that compliance leads to recollection, not vice versa).

5. Conclusions

To conclude, it seems premature to waive self-report survey items aiming to assess population hand hygiene behaviour within a “direct questions on handwashing” paradigm. Partitioning this behavioural domain into different attributes and using indices based on combinations of attributes may be an option to deal with overestimation tendencies in self-reports. Additionally, compliance estimates based on such indices may be used in interventions to provide feedback on behaviour, uncover discrepancies with relevant self-perceptions, and thus promote awareness and motivate better hand hygiene compliance in the population, which becomes of paramount importance in pandemic situations.

Notes

1. This manuscript conforms to the STROBE- (STRengthening the Reporting of Observational studies in Epidemiology-) Statement for cross-sectional studies (https://www.strobe-statement.org/index.php?id=strobe-home; see Supplementary Material).

2. No third-party funding has been received for the work carried out to prepare the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijheh.2020.113590.

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