First questionnaire with measurement equivalence between physicians and nurses to assess individual determinants of compliance with surgical site infection prevention: cross-sectional survey results from the WACH-study

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Short Report

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Abstract

Background

Compliance to prevent healthcare-associated infections varies between physicians and nurses. Understanding these differences is the key to adapt, i.e., tailor interventions to promote compliance. To measure determinants to be taken into account in tailoring processes, reliable and valid instruments with measurement equivalence (ME) across professional groups are needed.

Aim

To determine the reliability, validity, and ME of questionnaire scales to assess determinants of compliance to prevent surgical site infections (SSI) based on the Capability|Opportunity| Motivation–Behaviour model (COM-B), and explore their associations with self-reported compliance.

Methods

Self-reported SSI-preventive compliance and COM-B-determinants were assessed in a questionnaire survey of 90 physicians and 193 nurses working in nine departments in six German hospitals outside the university sector. Single- and multi-group confirmatory factor analyses, t-tests, and multiple linear regression analyses were performed.

Findings:

Scales for individual determinants (capability, motivation, planning) but not environmental determinants (opportunities) showed reliability and validity among both physicians and nurses, and ME across these groups. No group differences were found in compliance and determinants. Capability ($\beta = .301$) and planning ($\beta = .201$) showed theory-conform associations with self-reported compliance among nurses, not physicians. Additionally, both tended to mediate the association of motivation.

Conclusion

The scales for motivation, capability, and planning regarding SSI-preventive compliance rendered reliable and valid scores for physicians and nurses in surgery. Due to ME, they provide true comparisons between both groups in German hospitals. Such scales for environmental determinants (opportunities) have yet to be developed. Associations of individual determinants with self-reported compliance were in line with theory among nurses.

Background

In infection prevention and control (IPC), (non-)compliance of healthcare workers’ (HCW) with evidence-based measures remains the bottleneck for successful implementation (1). One classic example is hand hygiene (HH), with compliance remaining suboptimal and ubiquitously higher among nurses than physicians (2–5). This had led to increased efforts to understand compliance using, among others, behavioural science (6–8). One aim is to tailor, i.e., adapt promotion strategies to HCW and their contexts, since such adaptation increases the adoption of preventive measures (9, 10). In other words, implementation interventions to improve professional IPC compliance should account for prospectively identified psychosocial determinants of practice.

For instance, two studies (11, 12) have developed questionnaire scales for individual capability (C), opportunity (O) and motivation (M) for HCW’s HH behaviour (B) using the COM-B model (13, 14). This framework describes physical skills/strengths and psychological stamina/knowledge (C), physical and social environmental factors (O), and reflective and automatic motivational processes, e.g., deliberate plans and evaluations, and emotional reactions and impulses (M) (13, 14). While both studies used confirmatory factor analysis (CFA) to determine scale reliability and validity, they pooled data from physicians and nurses. Hence, they did not determine measurement equivalence (ME; synonym: measurement invariance) across both groups. Usually tested by multiple group confirmatory factor analysis (MGCFA), i.e., an extension of CFA (15, 16), ME has been argued to be a precondition for comparing different groups, e.g., regarding means, and its absence to lead to potentially spurious interpretations (17, 18).
To explore ME across physicians and nurses in COM-factors, this short report follows up on a survey of orthopaedic physicians in which COM-B was applied to compliance with measures to prevent surgical site infections (SSI) (19). Exploratory factor analysis (EFA) of 12 items on individual COM determinants resulted in three factors (“capability”, “motivation”, and a third one labelled “planning”), and an EFA of six items on environmental determinants in one factor (“opportunity”) (19). Subsequently, this questionnaire was used in baseline assessments of a cluster-randomised controlled trial on implementation interventions to prevent SSI (20). Using this data, in the following analyses we aimed to determine the validity and reliability of the scales developed in (19) among physicians and nurses using CFA ((19) only included physicians), and the ME of the scales across these groups using MGCFA. Additionally, for valid, reliable, and equivalent scales, we explored associations between COM factors and self-reported SSI-preventive compliance.

Methods

In the WACH trial (20), a cross-sectional survey using a self-administered written IPC questionnaire was conducted from March to October 2019. Six non-university hospitals were recruited to transfer the behavioural approach of a previous university hospital study (21, 22) (for further information see declarations on Ethics approval and consent to participate and Funding below). In each hospital, physicians and nurses working in either the general/visceral surgery, orthopaedic/trauma surgery, or anaesthesiology department were invited to participate. Sufficient copies of the questionnaire were provided to each IPC team, who distributed them and obtained informed consent. Completion time of the survey depended on hospital size, the number of participating departments, and working capacities of the IPC team, and ranged from 14 to 97 days (x=56, standard deviation (SD) = 29.3).

The questionnaire included a total of 94 items addressing compliance with 26 SSI preventive clinical interventions, COM determinants, awareness of in-house implementation interventions, and socio-demographics. Participants were asked to rate 18 items representing the COM factors on 7-point-Likert scales. According to the EFA of the pre-test (19), the numbers of items measuring “capability”, “opportunity”, “motivation”, and “planning” were six, six, four, and two, respectively (for items, see Additional file 1). SSI-preventive measures for which self-reported compliance was assessed were selected according to national recommendations and guidelines (23, 24) (see Additional file 2). For each measure, participants were asked to indicate the number of instances in which they executed it compliantly (as a percentage of instances in which it was indicated). When participants considered a measure not to fall within their responsibility, they could choose “not applicable”. The index for overall individual compliance was based on the same items and algorithmization used in (19): the sum of all compliance rates was divided by the number of measures for which responsibility had been indicated.

Participants reported their sex, age (in categories [<18|18−30|31−40|41−60|60+] years) to comply with data protection regulations), and specialty (see Table 1). Based on the latter, participants were categorised as physician or nurse.

IBM SPSS Statistics v27 was used for t-tests and regressions, and R’s lavaan-package v0.6-12 for CFA and MGCFA. To account for missing data and multivariate normality assumptions during CFA and MGCFA, a robust full-information-maximum-likelihood estimate was used (25, 26). Two models were tested based on the EFA in (19): one with the three individual determinants “capability”, “motivation”, and “planning”, and one with the environmental determinants, i.e., “opportunity”.

CFA was used to test for construct validity with a model fit determined by Root-Mean-Square-Error of Approximation (RMSEA) ≤ .08 (27), Standardized Root Mean Square Residual (SRMR) ≤ .08 (28), and Comparative-Fit-Index (CFI) ≥ .9 (29). For each construct, the average variance extracted (AVE) was calculated based on the CFA results and used to test the Fornell-Larcker criterion (FLC). An AVE > .5 indicates convergent validity (i.e., explained variance larger than error variance), whereas a met FLC indicates discriminant validity (30). Factor loadings (correlations between items and constructs) > .7 indicate item reliability (26). Regarding factor reliability, Cronbach’s α is often used to test for; but its interpretation is flawed given unequal factor loadings (31). Hence, model-based reliability, i.e., McDonald’s ω, was additionally calculated based on the CFA results (32). Good model fit is required for reasonable interpretation of ω and for both, α and ω, values > .7 are considered acceptable (26).

In case of satisfactory model fit in CFA, MGCFA was used to test for ME across physicians and nurses. To test the assumptions of sufficient model fit in both groups, stratified CFAs were performed (16). ME is not dichotomous but has hierarchical levels (15, 16). Weak ME (“metric invariance”) implies that the constructs’ relationships within the model can be compared across groups, while strong ME (“scalar invariance”) implies that the constructs’ means can be meaningfully compared. For metric invariance, factor loadings are held equal, i.e., constrained across groups; for scalar invariance, intercepts are constrained as well (15). Each level of ME was confirmed if the model fit did not decrease, with ΔCFI < .01 as cut-off (15). If, at any ME level, the model did not meet this criterion, partial invariance could still be obtained by releasing single constraints (16).
To compare physicians and nurses, t-tests were performed for the compliance index, COM scales with ME and the number of SSI-preventive measures participants considered to be responsible for ("responsibility"), intercorrelations of COM scales with ME, and multiple hierarchical linear regressions to explore associations between these scales and self-reported compliance. In each first model, participants’ specialty (surgery vs. anaesthesiology) and the "responsibility"-variable were entered as confounders. In the second model, "motivation" was added, followed by "capability" (third model). As a specific factor that had emerged in the pre-test results (19), "planning" was added in a final model.

**Results**

N = 336 HCW participated (response rate: 31.5%). N = 18 had missing data on the variable indicating being physician or nurse. The calculable response rates were 28.4% for physicians and 30.4% for nurses. N = 3 physicians and N = 32 nurses were excluded from analysis due to missing data (> 20%) on COM items. The analysis sample consisted of N = 90 physicians and N = 193 nurses. Sample characteristics are presented in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Physicians</th>
<th>Nurses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>41 (46.1%)</td>
<td>155 (82.4%)</td>
<td>196 (70.8%)</td>
</tr>
<tr>
<td>male</td>
<td>48 (53.9%)</td>
<td>33 (17.6%)</td>
<td>81 (29.2%)</td>
</tr>
<tr>
<td><strong>Age (in years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 18</td>
<td>1 (1.1%)</td>
<td>3 (1.1%)</td>
<td>3 (1.1%)</td>
</tr>
<tr>
<td>18 – 30</td>
<td>13 (14.8%)</td>
<td>51 (27.6%)</td>
<td>64 (23.4%)</td>
</tr>
<tr>
<td>31 – 40</td>
<td>28 (31.8%)</td>
<td>48 (25.9%)</td>
<td>76 (27.8%)</td>
</tr>
<tr>
<td>41 – 50</td>
<td>23 (26.1%)</td>
<td>36 (19.5%)</td>
<td>59 (21.6%)</td>
</tr>
<tr>
<td>51 – 60</td>
<td>18 (20.5%)</td>
<td>39 (21.1%)</td>
<td>57 (20.9%)</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>6 (6.8%)</td>
<td>8 (4.3%)</td>
<td>14 (5.1%)</td>
</tr>
<tr>
<td><strong>Specialty</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specialist, surgery</td>
<td>42 (46.7%)</td>
<td>42 (14.8%)</td>
<td></td>
</tr>
<tr>
<td>Registrar, surgery</td>
<td>19 (21.1%)</td>
<td>19 (6.7%)</td>
<td></td>
</tr>
<tr>
<td>Specialist, anaesthesiology</td>
<td>14 (15.6%)</td>
<td>14 (4.9%)</td>
<td></td>
</tr>
<tr>
<td>Registrar, anaesthesiology</td>
<td>13 (14.4%)</td>
<td>13 (4.6%)</td>
<td></td>
</tr>
<tr>
<td>Physician assistant</td>
<td>2 (2.2%)</td>
<td>2 (0.7%)</td>
<td></td>
</tr>
<tr>
<td>Ward nurse</td>
<td></td>
<td>97 (50.3%)</td>
<td>97 (34.4%)</td>
</tr>
<tr>
<td>Perioperative nurse</td>
<td></td>
<td>62 (32.1%)</td>
<td>62 (21.9%)</td>
</tr>
<tr>
<td>Nurse anaesthetist</td>
<td></td>
<td>34 (17.6%)</td>
<td>34 (12.0%)</td>
</tr>
<tr>
<td><strong>Department</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthopaedics/Trauma surgery</td>
<td>37 (41.1%)</td>
<td>71 (36.8%)</td>
<td>108 (38.2%)</td>
</tr>
<tr>
<td>General/Visceral surgery</td>
<td>21 (23.3%)</td>
<td>53 (27.5%)</td>
<td>74 (26.1%)</td>
</tr>
<tr>
<td>Both surgical departments</td>
<td>5 (5.6%)</td>
<td>35 (18.1%)</td>
<td>40 (14.1%)</td>
</tr>
<tr>
<td>Anaesthesiology</td>
<td>27 (30.0%)</td>
<td>34 (17.6%)</td>
<td>61 (21.6%)</td>
</tr>
</tbody>
</table>

*Note: Any data not adding up to the relevant total due to missing values.*
For the three-factor model of individual determinants, CFA revealed an excellent model fit ($\chi^2 = 111.3$, $df = 51$, $p < .001$, RMSEA = .065, SRMR = .039, CFI = .95), with most factor loadings >.7 (exceptions: .69 and .67), and reliability for “capability” (Cronbach’s $\alpha = .90$, McDonald’s $\omega = .92$), “motivation” ($\alpha = .85$, $\omega = .86$), and “planning” ($\alpha = .89$, $\omega = .89$; see Fig. 1). Convergent and discriminant validity were observed for every construct. Thus meeting criteria for MGCFA, ME testing was performed. As Table 2 shows, MGCFA revealed both metric and scalar invariance, as the decline in model fit was tolerable ($\Delta$CFI = −.006 and $\Delta$CFI = .005, respectively).

![Table 2](image)

Table 2: CFA and MGCFA results of measurement invariance testing

<table>
<thead>
<tr>
<th></th>
<th>$\chi^2$</th>
<th>$p$</th>
<th>df</th>
<th>RMSEA (90% CI)</th>
<th>SRMR</th>
<th>CFI</th>
<th>$\Delta$CFI#</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>One-factor model of external determinants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>86.6</td>
<td>&lt; .001</td>
<td>9</td>
<td>.175 (.145; .206)</td>
<td>.067</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td><strong>MGCFA</strong>§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-factor model of internal determinants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>111.3</td>
<td>&lt; .001</td>
<td>51</td>
<td>.065 (.050; .079)</td>
<td>.039</td>
<td>.95</td>
<td></td>
</tr>
<tr>
<td>Physicians</td>
<td>97.8</td>
<td>&lt; .001</td>
<td>51</td>
<td>.101 (.073; .128)</td>
<td>.052</td>
<td>.93</td>
<td></td>
</tr>
<tr>
<td>Nurses</td>
<td>97.7</td>
<td>&lt; .001</td>
<td>51</td>
<td>.069 (.050; .088)</td>
<td>.041</td>
<td>.94</td>
<td></td>
</tr>
<tr>
<td><strong>MGCFA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted model</td>
<td>195.5</td>
<td>&lt; .001</td>
<td>102</td>
<td>.081 (.065; .096)</td>
<td>.045</td>
<td>.935</td>
<td></td>
</tr>
<tr>
<td>Metric invariance</td>
<td>195.8</td>
<td>&lt; .001</td>
<td>111</td>
<td>.073 (.058; .089)</td>
<td>.047</td>
<td>.941</td>
<td>− .006</td>
</tr>
<tr>
<td>Scalar invariance</td>
<td>211.4</td>
<td>&lt; .001</td>
<td>120</td>
<td>.073 (.058; .088)</td>
<td>.050</td>
<td>.936</td>
<td>.005</td>
</tr>
</tbody>
</table>

*Notes:* CFA: confirmatory factor analysis; MGCFA: multiple-group confirmatory factor analysis; $\chi^2$: Chi-square test statistic, $p$: p-value; df: degrees of freedom; RMSEA: Root-Mean-Square-Error of Approximation; SRMR: Standardized Root Mean Square Residual; CFI: Comparative-Fit-Index.

# $\Delta$CFI was only calculated during MGCFA

§ MGCFA was not performed on the one-factor model due to insufficient model fit in CFA

Among nurses, the correlations of the scale “motivation” were $r = .59$ with “capability” and $r = .30$ with “planning”, and of “capability” with “planning” $r = .35$. Among physicians, these were $r = .60$, $r = .36$ and $r = .37$, respectively (all $p < .001$; see Additional file 3 for all bivariate correlations, including those for “responsibility”).

For the one-factor model of environmental determinants, CFA revealed insufficient model fit ($\chi^2 = 86.6$, $df = 9$, $p < .001$, RMSEA = .175, SRMR = .067, CFI = .83), precluding consideration in further analysis.

Comparing physicians and nurses, t-tests revealed significant differences neither in compliance ($t(281) = .486$, $p = .627$) nor individual determinants (capability: $t(153.7) = -1.312$, $p = .192$; motivation: $t(138.5) = .169$, $p = .866$; planning: $t(165.1) = - .045$, $p = .964$), but in the number of measures they had reported responsibility for (physicians: $\bar{x} = 17.1$, SD = 4.9; nurses: $\bar{x} = 10.1$, SD = 4.7; $t(167.5) = 10$, $p < .001$).

Results of the linear regression models are presented in Table 3. Among physicians, the final model explained 6% of the variance in self-reported compliance ($F(5;79) = 2.08$, $p = .077$). Being a surgeon (vs. anaesthetist) was the regressor with the highest standardized coefficient ($\beta = .196$), but like all others was statistically insignificant ($p = .123$).

Among nurses, the final model explained 25.4% of the variance ($F(5;164) = 12.52$, $p < .001$). In the first model, “speciality” and “responsibility” accounted for 10.2%. In the final model, “capability” ($\beta = .301$, $p < .001$) and “planning” ($\beta = .201$, $p = .006$) showed the strongest associations. Adding them led to a $\beta$ decrease for “motivation”, which predicted compliance significantly in the second model (Table 3).
Table 3
Results of hierarchical multiple linear regressions for physicians and nurses.

<table>
<thead>
<tr>
<th></th>
<th>Nurses (N = 170)</th>
<th>Physicians (N = 85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>10.63 10.96 13.18 12.52</td>
<td>2.92 2.78 2.53 2.08</td>
</tr>
<tr>
<td>corr R sq</td>
<td>.102 .150 .224 .254</td>
<td>.044 .060 .068 .060</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt; .001 &lt; .001 &lt; .001 &lt; .001</td>
<td>&lt; .001 &lt; .001 &lt; .001 &lt; .001</td>
</tr>
<tr>
<td>(Constant)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>45.84 12.29 11.22 11.55</td>
<td>23.45 13.31 12.77 12.71</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt; .001 &lt; .001 &lt; .001 &lt; .001</td>
<td>&lt; .001 &lt; .001 &lt; .001 &lt; .001</td>
</tr>
<tr>
<td>Surgeon (ref. anaesthesiologist)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>3.58 2.79 1.70 1.74</td>
<td>1.93 1.83 1.58 1.56</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>.265 .207 .125 .126</td>
<td>.241 .227 .198 .196</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt; .001 .006 .091 .084</td>
<td>.057 .070 .118 .123</td>
</tr>
<tr>
<td>Responsibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>3.46 3.11 3.17 2.86</td>
<td>.25  .26  .09  -.01</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>.256 .225 .220 .196</td>
<td>.031 .033 .011  -.001</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt; .001 .002 .002 .005</td>
<td>.806 .792 .929 .996</td>
</tr>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>3.23 .53 .24 .24</td>
<td>1.55  .45  .32</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>.237 .044 .020 .020</td>
<td>.164 .060 .043</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>.002 .602 .811</td>
<td>.126 .653 .754</td>
</tr>
<tr>
<td>Capability</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>4.09 3.42</td>
<td>1.30  1.19</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>.357 .301</td>
<td>.180  .166</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt; .001 &lt; .001</td>
<td>.196  .238</td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>2.78</td>
<td>.60</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>.201</td>
<td>.071</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>.006</td>
<td>.550</td>
</tr>
</tbody>
</table>

Notes: F: F-test statistic; corr R sq: corrected R square; p: p-value; t: t-test statistic; β: standardized regression coefficient

Discussion
The scales previously presented for “motivation”, “capability” and “planning” as COM-B determinants of compliance to prevent SSIs (19) have been shown to be valid and reliable among physicians and nurses. By establishing ME across physicians and nurses, comparisons between these groups using these scales are unspurious and can be interpreted meaningfully. Additionally, while physicians and nurses differed neither in determinants nor self-reported compliance, we found significant associations of motivation, capability and planning with self-reported compliance among nurses, but not physicians. Based on correlative and hierarchical regression results, the association of motivation with compliance may be inferred as mediated by capability and planning.
Before discussing these findings, strengths and limitations of this study should be considered. The analysis was confirmatory not only by its statistical approach but by replicating a former analysis (19) as well. Additionally, to our knowledge this is the first study on ME of psychosocial determinants of compliance with IPC measures, in this case to prevent SSI.

Regarding limitations, first the survey response rate was just above 30%, which was lower than the global average of 53% among surgical doctors (33). This led to a nearly undersized sample for the MGCFA among physicians. While indirect approaches such as those used in the present survey (i.e., distributing questionnaires from project teams to HCW via in-house IPC teams) were not reviewed (33), probably the lack of tangible incentives and questionnaire personalization, and questionnaire length (34), affected the response. Additionally, the 73% response rate among surgical doctors in (19) was achieved in a university hospital clinic, in which HCW may have a higher affinity to research, and extraordinary support was provided by the medical director. While efforts should be made to increase response rates, there is a decreasing trend in response rates among surgical doctors (34), and the present rate at least falls within one standard deviation of the 2019 mean reported in (34).

Second, the 18 COM items represent only a sample of facets of compliance determinants. After all, all 14 domains and 84 constructs of the Theoretical Domains Framework, i.e., the most integrative, granular classification of theoretical constructs relevant to behaviour change, can be mapped to the COM components (35, 36). Thus, the items rather reflect the need for a concise HCW survey tool and the bid to focus on the most relevant facets based on the best available evidence and expertise in the transdisciplinary WACH study group.

Third, one could argue that it remains unclear how the COM scales refer to the compliance behaviours because respondents were asked to rate the items with all preventive measures they felt responsible for in mind. That is, models such as COM-B were developed to identify determinants for individual behaviours within change intervention design processes (13, 14) for the simple reason that different determinants may be important for different behaviours. While this argument certainly holds validity, a key trend in SSI prevention has been the use of bundles (37–41), i.e., sets of “...evidence-based interventions...that, when implemented together, will result in significantly better outcomes than when implemented individually” (42). Thus, compliance is increasingly defined in terms of more than one measure simultaneously. In this sense, the operationalization of SSI preventive compliance in this study may be viewed as a kind of “subjective bundle”-approach. Yet, we concede that even such bundles may have to be untied in order to delineate specific interventions to promote compliance.

Fourth, this observational study used a cross-sectional design, which implies that no specific direction of causation could be established. Thus, employing the scales in longitudinal studies is needed to assess their causal structure and sensitivity to change.

Finally, the data was collected before the COVID-19 pandemic. Physicians and nurses may now differ in self-reported compliance and COM factors. However, the results of CFA and MGCFA, i.e., the evidence base for the validity, reliability and ME of the scales, should be robust, as these statistical analyses are based on the structure of item responses, not the values themselves.

Keeping the limitations in mind, results can be rationalized as follows. First, for SSI prevention, this study provides reliable and valid questionnaire instruments with ME across physicians and nurses for individual, but not for environmental determinants of compliance. Possibly, the contextual attributes of the participating hospitals, which could not be accounted for due to sample sizes not allowing multilevel analysis, affected HCW's perceptions of their work environment. As previous studies have emphasised the importance of environmental determinants of IPC compliance (43–46), developing improved measures of opportunities remains an important task.

Second, the results replicated the factor “planning” as an independent construct (19). Whereas in original COM-B terminology, planning represents a facet of reflective motivation (13, 14), it seems that implementation-oriented cognitions stands out as a specific determinant of (at least self-reported) behaviour, especially given the large number of SSI prevention measures. In addition, this factor scored lowest across all scales by far, both among physicians and nurses (see Additional_file_1). Thus, planning action and coping with barriers may be particularly important for tailoring interventions to promote compliance by assisting HCWs to overcome intention-behaviour-gaps (47, 48), i.e., being motivated but not being able to translate this into action. Generally, we would like to stress that this result is not to be considered as an extension of COM-B, even though we stuck with the labels “motivation” and “capability” for the other factors representing individual determinants.

Finally, unlike previous studies (43–46, 49), physicians and nurses in this sample did not differ in psychosocial determinants of compliance. As ME for these was established (to our knowledge, for the first time in the SSI prevention field, other tests being from other areas (50–52)), this raises the question of whether differences found in earlier studies are spurious (53). In other words, differences found using instruments with no or insufficient ME may result from different understandings of the items but may not reflect true differences in the underlying, i.e., latent variable. This supports the call for IPC to more determinedly deliberate issues related to construct validity (54), not only in regard to measuring compliance, but to determinants of compliance as well.
At the same time, there were differences in the regressions modelling self-reported compliance. For physicians, explained variance was < 10%, and no regressor showed a significant association. In contrast, the final model for nurses explained over 25% of the variance, “planning” and “capability” were associated with compliance, and both potentially mediated the effect of motivation. Keeping in mind that – consistent with HH results of the present survey – the self-reported compliance rate was similar between physicians and nurses, and observed compliance is consistently lower among physicians (2–5, 55), these differences in predictive validity can be interpreted in different ways. Either the determinants do not work as well for self-reported compliance among physicians because their overestimation is larger than that among nurses (55), and thus these self-reports do not reflect compliance but overestimation. Or the individual facets of the COM-B model, at least as measured by the scales validated here, are simply not so relevant to physicians’ compliance, which would be consistent with the limited success previous research has had in promoting physicians’ compliance (2–5, 10, 22). This would pose the question as to which factors are relevant to physicians. Finally, given that in the pre-test, regression results for physicians from a tertiary care university orthopaedic department (19) were much more similar to the pattern found for nurses in the present study, there is the possibility that matters are more chaotic than expected by theory, i.e., highly context-specific and/or dependent on unknown factors. This "chaos" may emphasise the need to tailor any intervention aiming to promote compliance even more meticulously to the situation prevailing "on the ground". Moreover, it would point to the added value of studies which would make it possible to link data on psychosocial determinants with observed compliance at the level of individual HCW – “despite” or rather, needless to say, in compliance with ethical and data protection issues (if at all possible).

In sum, this study provides the first instrument for motivation, planning, and capability as individual determinants of SSI-preventive compliance with demonstrated ME across physicians and nurses. As an instrument with demonstrated ME (at least for the original German version), it allows valid interpretation of group comparisons and thus adds to the understanding of how and why health care professions differ (or don't) in IPC compliance. In conclusion, it contributes to the study of physicians' compliance as a key contemporary IPC topic (10, 56), and follows the call for "...easy-to-use, valid tools to provide data on the factors that influence the...behaviour of healthcare professionals" (11).

Abbreviations

- average variance extracted (AVE)
- Capability|Opportunity|Motivation–Behaviour Model (COM-B)
- Comparative-Fit-Index (CFI)
- confirmatory factor analysis (CFA)
- Exploratory factor analysis (EFA)
- Fornell-Larcker criterion (FLC)
- healthcare workers (HCW)
- hand hygiene (HH)
- infection prevention and control (IPC)
- measurement equivalence (ME)
- multiple group confirmatory factor analysis (MGCFA)
- Root-Mean-Square-Error of Approximation (RMSEA)
- standard deviation (SD)
- Standardized Root Mean Square Residual (SRMR)
- surgical site infection (SSI)

Declarations

This manuscript complies with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) Statement for cross-sectional studies (https://www.strobe-statement.org/index.php?id=strobe-home).

Ethics approval and consent to participate

The WACH study was approved by the Ethics Committee of the Faculty of Medicine at the University of Leipzig (vote no. 034/18-ek) and the ethics committees of the medical associations in all the federal states involved (Lower Saxony, North Rhine Westphalia, Rhineland...
The questionnaire survey, from which the data are reported here, was approved by all employee committees of the participating hospitals. All participants obtained informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the senior author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

KMEK and TvL substantially contributed to the analysis and interpretation of the data, and drafted the manuscript. IT, MS, CK, IFC and TvL made substantial contributions to the acquisition of the data. All authors made substantial contributions to the conception and design of the work, substantively revised the work, approved the submitted version of the manuscript, agreed to be personally accountable for their own contributions, and ensured that questions related to the accuracy or integrity of any part of the work, even ones in which they were not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. All authors read and approved the final manuscript.

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Previous presentation of results

Preliminary results were presented in form of a poster on September 6, 2022, at the 74\textsuperscript{th} Annual Meeting of the German Society for Hygiene and Microbiology (DGHM) in Berlin, Germany.

References


Figures

Figure 1

Standardized solution for CFA on three-factor model.

Note:
The arrows pointing from the measurement errors (circles) to the items (rectangles) display error variances, while those pointing from the constructs (in ellipses) to the items display factor loadings, and the curved double arrows correlations between constructs; AVE is the average variance extracted and should be > .5 and $\omega$ is McDonald’s $\omega$ and should be > .7

Supplementary Files
This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1.docx
- AdditionalFile2.docx
- AdditionalFile3.docx