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Measuring menstrual hygiene experience: Development and validation of the Menstrual Practice Needs Scale (MPNS-36)

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Complete List of Authors:	Hennegan, Julie; Johns Hopkins University Bloomberg School of Public Health, Environmental Health and Engineering Nansubuga, Agnes ; Irise Institute East Africa Smith, Calum; Irise International Redshaw, Maggie; NPEU, Department of Population Health Akullo, Agnes; Irise Institute East Africa Schwab, Kellogg; Johns Hopkins University Bloomberg School of Public Health, Environmental Health and Engineering
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8 3 **Measuring menstrual hygiene experience: Development and validation of the**
9 4 **Menstrual Practice Needs Scale (MPNS-36)**
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18 Julie Hennegan¹ (ORCID: 0000-0003-2011-1595)

19 9 Agnes Nansubuga²

20 10 Calum Smith³

21 11 Maggie Redshaw⁴

22 12 Agnes Akullo²

23 13 Kellogg J. Schwab¹ (ORCID: 0000-0002-4966-8517)
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25
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29
30 15 ¹ The Water Institute, Department of Environmental Health and Engineering, Johns Hopkins
31 16 Bloomberg School of Public Health, Baltimore, MD, USA

32 17 ² Irise Institute East Africa, Jinja, Uganda

33 18 ³ Irise International, Sheffield, UK

34 19 ⁴ Policy Research Unit in Maternal Health & Care, National Perinatal Epidemiology Unit (NPEU),
35 20 University of Oxford, Oxford, UK
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43 24 Words: 6,225
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45 25

46 26 Correspondence:

47 27 Dr. Julie Hennegan

48 28 Johns Hopkins Bloomberg School of Public Health

49 29 615 N Wolfe St

50 30 Baltimore MD 21205

51 31 United States

52 32 jhenneg1@jhu.edu

53 33 Twitter: [julie_hennegan](https://twitter.com/julie_hennegan)
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ABSTRACT

Objectives. This study describes the development and validation the Menstrual Practice Needs Scale (MPNS-36) which measures the extent to which females' menstrual practices and environments meet their needs.

Methods. A 54-item pool was developed following systematic-review of qualitative and quantitative studies and expert feedback. Item reduction and scale validation were undertaken using a cross-sectional survey of 538 menstruating schoolgirls in Soroti, Uganda. Test-retest reliability was assessed in a sub-sample of 52 girls two weeks after the first administration. Construct validity was tested through relationships with hypothesised correlates: confidence to manage menses, self-reported school absenteeism, and mental health symptoms.

Results. The final MPNS-36 comprises 28 items applicable to all respondents, and 8 items capturing washing and drying experiences for those reusing menstrual materials. A four-factor solution for the core 28 items was the best fit for the data (RMSEA=0.028-0.029; CFI=0.961-0.964; TFI=0.957-0.959), supplemented by two factors for reuse (RMSEA=0.021-0.030; CFI=0.987-0.994; TFI=0.981-0.991). Subscale and total scores were calculated as mean scores to support accessibility for practitioners. Subscales were 'material and home environment needs' (11 items, $\alpha_{\text{ordinal}}=0.84$), 'transport and school environment needs' (5-items, $\alpha_{\text{ordinal}}=0.73$), 'material reliability concerns' (3-items, $\alpha_{\text{ordinal}}=0.55$), 'change and disposal insecurity' (9-items, $\alpha_{\text{ordinal}}=0.80$), 'reuse needs' (5-items, $\alpha_{\text{ordinal}}=0.76$), and 'reuse insecurity' (3-items, $\alpha_{\text{ordinal}}=0.56$). Relationships between subscales and hypothesised correlates supported validity. Home- and school-based items were more strongly associated with confidence to manage menstruation at home and school, respectively. Higher scores predicted not missing school during the last menstrual period (total score: OR=2.62, 95%CI=1.52-4.50). Test-retest reliability was moderate (total score: ICC_(2,1)=0.69).

Conclusions. The MPNS-36 demonstrated acceptable reliability and validity. It is the first measure to capture women and girls perceived menstrual hygiene and may be used across a range of study designs to assess menstrual needs. Future research should explore the suitability and sensitivity of the measure across contexts.

Keywords: menstrual hygiene; menstrual health; psychometrics; validation studies; outcome assessment

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Strengths and Limitations of this Study

- This study described the development and validation of the Menstrual Practice Needs Scale (MPNS-36) and explains the conceptual justification for the measure
- Measure development drew on systematic reviews, and findings from studies of measurement challenges in menstrual health research across a range of contexts
- The MPNS-36 provides a measure of the degree to which the practices and environments used in managing menstrual bleeding meet respondents' needs.
- There were no existing validated measures of menstrual experience against which to demonstrate convergent and divergent validity of the scale
- The scale exhibited acceptable reliability and validity, but was tested in a single context and language, and requires further research on cross-cultural validity and use in a range of settings

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INTRODUCTION

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5 85 Reports of women's and girls' negative experiences of menstruation have led to an increasing
6 86 momentum to enact policies and programs to improve menstrual health.(1, 2) A growing body of
7 87 qualitative studies have described the challenges faced during menstruation and their implications
8 88 for women's and girl's health and social participation.(3, 4) Qualitative methods are well-suited to
9 89 capturing the nuances of menstrual experience. However, quantitative studies are often needed to
10 90 support decision making, evaluate interventions, and monitor progress. To date, quantitative studies
11 91 have struggled to engage with the complexity of menstrual experiences and have been limited by
12 92 the lack of available measures to capture core concepts.(5) Researchers have relied on study-based
13 93 questionnaires in the absence of evidence to direct question selection or provide insights on
14 94 measure reliability and validity.

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18 95 This study reports on the development and validation of a new measure to capture women's and
19 96 girls' perceptions of their menstrual management needs. Here we describe: the identification of the
20 97 constructs targeted for assessment, the development of the Menstrual Practice Needs Scale (MPNS),
21 98 and the pilot and validation of the measure in a sample of menstruating schoolgirls.

99 **Menstrual practice needs**

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25 100 Establishing ways to measure menstrual hygiene has been an ongoing gap and research priority in
26 101 the study of menstrual experience and interventions.(6-8) Good menstrual hygiene was initially
27 102 defined as *"women and adolescent girls using a clean menstrual management material to absorb or*
28 103 *collect blood that can be changed in privacy as often as necessary for the duration of the*
29 104 *menstruation period, using soap and water for washing the body as required, and having access to*
30 105 *facilities to dispose of used menstrual management materials."*(9) This highlighted females' physical
31 106 management of menses.(10-12) The term has since seen new iterations, drawing in other menstrual
32 107 needs including knowledge of the menstrual cycle and supportive socio-cultural environments free
33 108 from stigma and menstrual-related restrictions.(12-14) To capture these varied aspects, multiple
34 109 indicators with specific methods of assessment will be necessary. While the formal definitions of
35 110 menstrual hygiene and menstrual health continue to evolve, the need for measures capturing the
36 111 implicit core concepts remains unchanged.(8)

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40 112 To inform our measure development efforts, we undertook a systematic review and meta-synthesis
41 113 of extant qualitative studies of women's and girls' menstrual experiences in low- and middle-income
42 114 countries (see (3)). We synthesised findings from 76 eligible studies to identify salient themes and
43 115 their relationships, developing an integrated model of menstrual experience. Of the identified
44 116 components of menstrual experience emerging from the review, two focused on women's and girls'
45 117 physical management of menstrual bleeding; menstrual practices, and perceptions of menstrual
46 118 practices and environments.(3) In describing the former, authors of included studies highlighted the
47 119 range of practices undertaken to manage menses, often discussing the ways practices influenced
48 120 discomfort or health. In the review we highlighted the distinction between these behavioural
49 121 practices such as the type of material used, and individuals' perceptions of practices adequacy,
50 122 comfort, or reliability. Perceptions reflected individual preferences and past experiences, resources,
51 123 knowledge, expectations and the norms of their socio-cultural environments.

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55 124 Quantitative study of menstrual experience has frequently collected data on individuals' menstrual
56 125 practices.(7) We would argue that practices alone are not well placed to capture individuals'
57 126 satisfaction or concerns, a frequent target for improvement in menstrual health programs. Measures
58 127 assessing the type of material used do not reveal if this material was preferred, just as those
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3 128 capturing the quantity of materials used do not indicate if the user felt this was sufficient. Practices
4 129 may be classified as more favourable based on their associations with reproductive tract
5 130 infections,(15) but the usefulness of these categories is limited when considering program impacts
6 131 on other outcomes such as menstrual experience, psychosocial wellbeing or social participation. We
7 132 hypothesise that measures of individuals' perceived adequacy of practices and environments are
8 133 likely to more closely align with findings from qualitative research and predict social participation
9 134 and wellbeing, as they acknowledge that the same practices may be appraised differently due to a
10 135 range of individual and sociocultural influences. We propose that quantitative assessment should
11 136 include measures of women's perceptions along with their practices. Both approaches align with the
12 137 existing description of menstrual hygiene, which does not specify whether adequate materials,
13 138 disposal, cleanliness, or privacy are defined by investigators through top-down appraisal of
14 139 behaviours or defined by respondents' perspectives.

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18 140 Thus, in this study we aimed to develop a measure that can capture the extent to which
19 141 respondents' current menstrual management practices and environments are perceived to meet
20 142 their needs. We restrict the measure to the practices undertaken and environments used to manage
21 143 menstrual bleeding; hypothesising that different measures will be needed to address other
22 144 constructs relating to menstrual pain or knowledge which are outside the scope of this work. To test
23 145 construct validity, we hypothesised that perceptions of menstrual practice needs would predict
24 146 lower school absenteeism due to menstruation, higher confidence to manage menstruation, and
25 147 fewer mental health symptoms, based on past qualitative research.(3)

26 148 **Measurement considerations**

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30 149 MPNS development was informed by past research highlighting considerations for measurement
31 150 and preliminary investigations by our study team. First, past research has indicated that poor
32 151 attention to the full range of menstrual practices may provide a skewed appraisal of community
33 152 needs.(16) Further, fixation on one menstrual practice in measurement, such as the type of material
34 153 used, may lead to overemphasis on this aspect at the expense of others. The breadth of practices
35 154 undertaken was informed through systematic review of past research.(3) Practices identified for the
36 155 proposed measure were: menstrual materials used, frequency of changing materials, transportation
37 156 and storage of materials, handwashing during menstrual management, genital and body cleaning,
38 157 disposal of used materials, and methods of washing and drying materials, including access to a vessel
39 158 for holding water and the use of soap. This list is consistent with an independent qualitative study
40 159 which aimed to identify the breadth of practice challenges in India, lending further support to this
41 160 broad coverage.(12) A second consideration was informed by a preliminary study investigating the
42 161 location-dependency of menstrual practices. Through a cross-sectional study in Bangladesh, we
43 162 found that schoolgirls' self-reported menstrual practices, such as the material used, varied between
44 163 home and school environments, as did their confidence to manage menses. These findings suggest
45 164 that self-report items with unclear locations may not adequately reflect the experiences researchers
46 165 are aiming to measure.(17) Third, in focus group discussions (FGDs) with enumerators who had
47 166 implemented Performance Monitoring and Accountability (2020) surveys(18) in Niger, participants
48 167 reported that survey respondents rarely immediately understood the intention of items asking
49 168 whether their menstrual environment was 'private' or 'safe'. Enumerators frequently provided
50 169 clarifications based on their own understandings; which also differed. Findings from FGDs suggested
51 170 that 'privacy' and 'safety' as stand-alone terms may not be amenable to cross-cultural adaptation
52 171 and translation. Similar issues with the interpretation of 'privacy' were reported in an independent
53 172 field test of measures in Belize.(19) For questions aimed at capturing these concepts, we returned to
54 173 the qualitative studies from which they were drawn and identified worries about being seen or

174 harmed as origins of 'privacy' and 'safety' priorities. This approach aligned with a recent measure of
 175 sanitation insecurity.(20) Finally, practitioners and researchers alike recognise the sometimes
 176 contradictory requirements in wishing to best capture experiences and at the same time moderate
 177 participant fatigue and survey length. Thus, the measure needed to balance length with
 178 comprehensiveness.

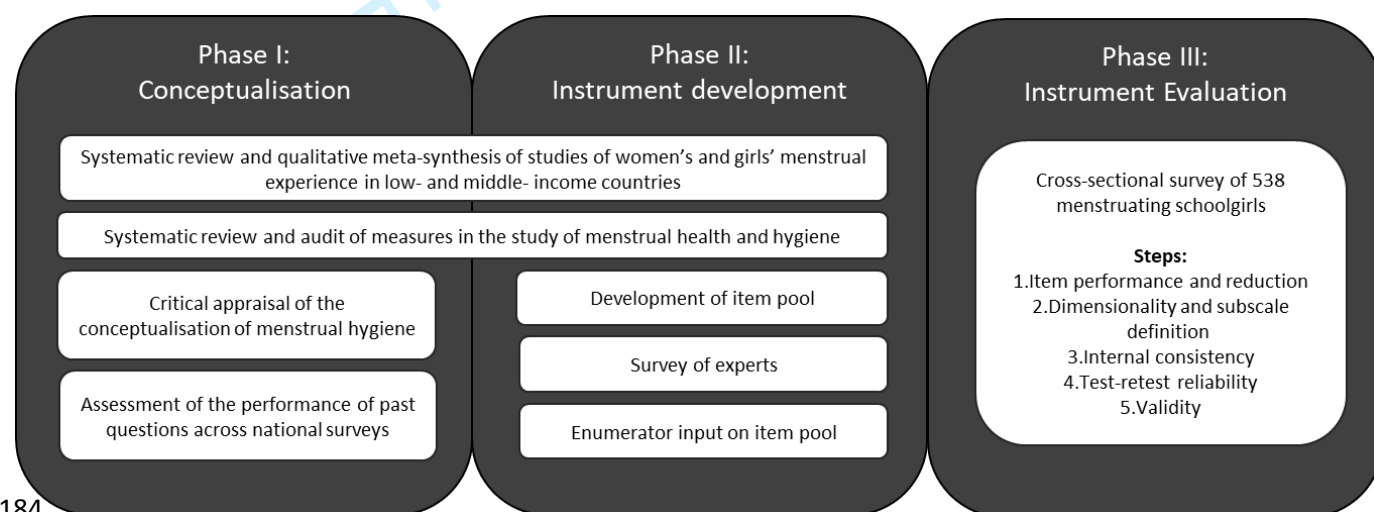
179 In sum, grounded in past research we defined menstrual practice needs as a core construct for
 180 measurement, and drew on past studies and preliminary research to guide item development.

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METHODS

183 The MPNS was developed across three phases, summarised in Figure 1.



184

185 **Figure 1.** Phases of development of the MPNS-36

186 Conceptualisation

187 In the first phase we identified constructs for assessment through systematic reviews of past
 188 research, assessed the need for new measures, and collated insights from the performance of past
 189 questions. This is described in the introduction.

190 Instrument development

191 Using our systematic review of qualitative studies, we collated the menstrual practices reported, and
 192 illustrative quotations of participants' perceptions of their practices and environments. These were
 193 included in the meta-synthesis report, see (3). We also utilised the full set of studies thematically
 194 coded in Nvivo 12 during the review, to provide an extensive set of quotations from which to draw
 195 scale items.

196 Following initial item generation, we undertook an online survey of experts. We invited members of
 197 the *East and Southern Africa Menstrual Hygiene Research Network*, and experts attending past *MHM*
 198 *in Ten*(21) meetings to participate. Twenty-three experts provided feedback on a selection of 19
 199 MPNS draft items. Participants identified as researchers (52%), practitioners (12%), or both (36%).
 200 Experts rated the usefulness of MPNS items and were invited to make comments. One item was
 201 removed from the pool due to poor ratings. Experts were also consulted regarding the response
 202 format with 68% endorsing a 4-point Likert option. A further 14% preferred a 3-point scale, with
 203 others suggesting dichotomous responses or responses varied by context/language.

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3 204 Sixteen items, professionally translated into French, were presented to resident enumerators
4 205 following collection of Performance Monitoring and Accountability (PMA) 2020 surveys in Niamey,
5 206 Niger. Items were presented as part of focus group discussions (FGDs) concerning the performance
6 207 of menstrual hygiene questions in PMA2020 surveys. Twenty resident enumerators from Niamey
7 208 provided feedback on the response options, with endorsement of a 4-point scale. During FGDs
8 209 enumerators indicated two potentially problematic items, suggesting that these were less likely to
9 210 be reported honestly by older adult women. These items were removed after piloting. During FGDs,
10 211 enumerators were asked for their impressions of what each item sought to capture. Their
11 212 interpretations matched our intentions for the items, supporting face validity.

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15 213 Final item wording was refined during translation and back-translation of items and research
16 214 assistant training for the validation study in Uganda.

17 18 215 **Instrument evaluation: Study sample and data collection**

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20 216 The target sample size was based on ten participants per item, a 10:1 ratio. A cross-sectional survey
21 217 was undertaken across 12 schools in Soroti, Uganda. Soroti is a regional urban centre in the Teso
22 218 sub-region of Eastern Uganda. Ugandan Demographic Household Survey (DHS) data from 2016
23 219 reports that 41.5% of the Teso region population places in the lowest national wealth quintile.
24 220 According to DHS, 39.2% of households had an observed hand washing location, 63.7% of females
25 221 had attended some primary school as their highest educational attainment.(22)

26
27 222 Schools recruited for the survey were already engaged with the partner NGO, Irise Institute East
28 223 Africa, were all government schools, and had been selected by the District Education Office as those
29 224 with the greatest need. Data were collected March-May 2019. Girls 12 years and older were
30 225 recruited from Primary (P) class levels P5-6, with expansion to P4 and P7 to achieve the required
31 226 sample size. In the previous year (October 2018), pupils in P6 received a menstrual education and
32 227 product (reusable sanitary pad) intervention. These students should have graduated to P7 by the
33 228 time of the survey. Grade repetition, school transfer, and the inclusion of some P7 students to
34 229 achieve the required sample meant some participants in this study had received an intervention 5-6
35 230 months prior to the survey.

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37 231 Female research assistants, local to the area were trained to deliver the survey. Paper surveys in
38 232 English were self-completed by girls in groups of no more than six, with research assistants providing
39 233 verbal instruction and translation in Ateso. Group surveys lasted approximately 75-90 minutes.

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42 234 Girls needed to be present at school and were recruited by class. If more girls were available than
43 235 could be surveyed, participants were selected using a simple randomisation technique (every third
44 236 girl across desk rows, repeated until the maximum number was met). Schools had at least two visits
45 237 for data collection. Almost all menstruating girls in participating classes were sampled to achieve the
46 238 target sample size. During the first data collection visit in the first 10 schools, one pre-selected
47 239 research assistant consented her group of up to 6 girls for re-test survey and recorded their names
48 240 next to an ID number. A reserve group of girls were also consented. Upon repeat visit, the target re-
49 241 test group were sought, with substitutions from the reserve group if needed.

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52 242 Data were entered into Qualtrics survey system by trained research assistants. Fifty surveys, 9.29%,
53 243 were entered twice for error screening. Data entry error rate was 1.59%.

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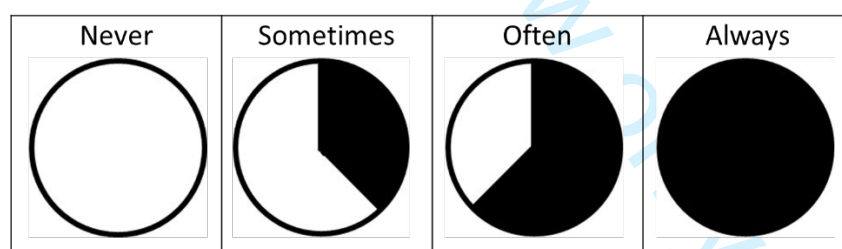
246 Survey content and question format

247 *Demographics.* Participants self-reported their age, class level, religion and grade repetition.
 248 Household resources were assessed using four items from the Afrobarometer lived poverty
 249 index,(23) indicating how often, over the past year, girls went without food, clean water, medicine
 250 and school supplies.

251 *Menstrual practices.* A suite of questions asking girls about their menstrual practices were
 252 asked as part of the concurrent development of the menstrual practices questionnaire (MPQ).
 253 Behaviours were reported for the last menstrual period, consistent with MPNS items. For the
 254 present study, we used items capturing the menstrual materials used during the last period at home,
 255 frequency of change of menstrual materials and location of material change.

256 *Last menstruation.* We asked girls to estimate the timing of their last menstrual period in
 257 broad terms “I have my period now”, “last week”, “within two weeks”, “within three weeks”, “one
 258 month” or “more than one month ago”. For girls undertaking the re-test survey, those selecting the
 259 first two options were coded as reporting on a new period.

260 *MPNS item pool.* The 54 draft items were included in the participant survey. On each page,
 261 participants were reminded that items referred to the last menstrual period. The items took the
 262 form of a personal statement followed by response options “never”, “sometimes”, “often”, and
 263 “always”. Response options were accompanied by a visual tool, see Figure 2. Participants had been
 264 familiarized with Likert responding earlier in the survey for agreement and disagreement items. The
 265 MPNS section of the survey was preceded by an activity. Research assistants had a large version of
 266 the visual tool and asked participants to report as a group on the frequency of a variety of school
 267 activities. For example, “How often do you have a lunch break during the school day?”, “How often
 268 do you have tests at school?”. The activity allowed research assistants to engage students regarding
 269 the selected response category.



271
 272 **Figure 2. Visual chart for MPNS item response options**

273 *Psychological symptoms.* Psychological health was assessed using a modified version of the
 274 Depression, Anxiety, Stress Scale (DASS-21).(24) For length, we selected only the depression and
 275 anxiety subscales and one item was removed from each scale. We removed anxiety item “I was
 276 aware of dryness of my mouth”, and depression item “I felt down-hearted and blue” as these were
 277 perceived to present challenges for translation. Language was simplified for translation, for example
 278 “I couldn’t seem to experience any positive feeling at all” was simplified to “I couldn’t experience any
 279 positive feelings”. Participants reported how often over the past week they experienced each
 280 statement in the list. Response options were simplified to: 0 “never”, 1 “sometimes”, 2 “often”, 3
 281 “almost always”. For analysis we used a total symptoms score, with depression and anxiety items
 282 transposed onto a 7-point scale to reflect the original. Total scores could range from 0 to 42.

283 *Confidence to manage menstruation.* Girls reported on a 4-point Likert scale from “Strongly
284 disagree” to “Strongly agree” their agreement with the statement “*I feel confident to manage my*
285 *menstrual period at home*” and “*at school*”. This was accompanied with a note that managing
286 menstruation means “*collecting materials, changing, washing drying and disposing of materials*
287 *during your period*”. Dichotomous responses of “confident” (agree or strongly agree) and “not
288 confident” (disagree or strongly disagree) were used for analyses.

289 *School attendance.* Participants self-reported if they “usually” missed school during
290 menstruation, providing “yes” or “no” responses. For comparison, girls reported if they missed
291 school during their last menstrual period “yes”, “no”, or “not applicable” if their last period did not
292 fall during school time.

293 **Instrument evaluation: Analyses**

294 Analyses were undertaken using Stata 15 and R Version 3.6.0.

295 Item responses were investigated through descriptive statistics. We used random split-halves of the
296 data to develop then test the emerging factor structure. Acknowledging the ordinal nature of the
297 data, exploratory factor analysis (EFA) with principal axis factoring was undertaken using the
298 polychoric correlation matrix. We used scree plots, eigenvalues >1 (Kaiser criterion), and theoretical
299 plausibility as criteria against which item reduction and final factor structure were determined. We
300 anticipated a-priori that any emergent factors would be correlated, and specified oblique rotation,
301 using *promax* with Kaiser normalisation. To maintain content validity, we prioritised coverage of
302 menstrual practices before selecting items with the highest factor loadings during reduction. Items
303 with loadings <0.30 were considered to have poor loading. During exploratory factor analysis we
304 permitted cross-loading for two items which applied to both school and home settings. These were
305 confined to a single factor in the final model.

306 We explored potential predictors of missing data including class level, age, and household resources
307 and identified no pattern of missing data. Little’s MCAR (missing completely at random) test was
308 non-significant $\chi^2=4107.57$, $p=0.246$, further supporting our assumption that there was no pattern. A
309 total of 13 girls (2.4%) were missing more than 2 items on the final 28-core item measure and were
310 excluded from final analysis. Missing data were deleted pairwise for EFAs.

311 We undertook confirmatory factor analysis (CFA) using the *lavaan* package in R. Reflecting the
312 ordinal nature of the data, we used a robust diagonally weighted least squares estimator (DWLS).
313 DWLS requires complete data. Multiple imputation using chained equations with the *mice* package
314 in R was undertaken for girls with 2 or fewer missing items. As *lavaan* does not support multiply
315 imputed data with DWLS estimation, we extracted ten imputed data sets and ran the CFA on each.
316 We combined factor loadings using Rubin’s rules.(25) There is little guidance on combining model fit
317 statistics across imputations, so we provide the range of root mean square error of approximation
318 (RMSEA), comparative fit index (CFI) and Tucker-Lewis index (TLI).(26) We considered RMSEA ≤ 0.05
319 as indicative of close fit, with RMSEA ≤ 0.08 as fair fit, and CFI and TFI ≥ 0.95 as indicative of
320 acceptable model fit.(27) Final CFA structure was compared to bi-factor and hierarchical models
321 using model fit statistics, item loadings and theoretical plausibility.

322 Measurement invariance was assessed by comparing the final CFA model between girls’ who
323 reported using only disposable sanitary pads at home, to others. We tested for threshold and
324 loading invariance, using updated guidance for multi-group CFA for ordinal data.(28, 29)

Internal consistency was computed using the polychoric, rather than Pearson, correlation matrix to generate an ordinal alpha.(30) We also provided Cronbach's alpha based on Pearson's correlations for comparison, although this has been suggested to underestimate associations in ordinal data.(30) We prioritised capturing experiences across the breadth of menstrual practices, recognising that measurement can bias attention towards particular practices. We also hypothesised that girls were likely to experience varied practices and environments with different levels of acceptability. Thus, a-priori, we were willing to sacrifice some degree of internal consistency for coverage. Nevertheless, we applied a conventional $\alpha_{\text{ordinal}} \geq 0.70$ as indicative of satisfactory reliability. Test-retest reliability was assessed using intra class correlation coefficients (ICCs) calculated using single-measure, two-way mixed-effects models, with absolute agreement.(31) We assessed test-retest reliability separately for girls reporting on the same or different menstrual period to their original survey. Although guidelines on acceptable ICCs are unclear, we considered an ICC between 0.50 and 0.75 to represent moderate reliability, and greater than 0.75 to represent good reliability.(31)

The lack of available measures for menstrual health constructs limited comparators for convergent or divergent validity. Drawing on hypotheses from qualitative research, we tested predictive validity though associations between the MPNS and confidence to manage menstruation, mental health and school absenteeism. Bivariate relationships were tested using Pearson's correlation coefficients for continuous variables, and binary logistic regressions for dichotomous outcomes (school absenteeism, and confidence to manage menstruation).

344

345 RESULTS

346 Participants

347 A total of 538 menstruating girls were surveyed. The mean age of the sample was 14.49 (SD=1.20).
 348 Self-reported ages were 12-19, with one girl indicating 11 years on the survey but reporting being 12
 349 during eligibility screening. Most of the sample were drawn from Primary Class Level (P)6, 59.29%,
 350 with an additional 18.40% from P5, 16.91% from P7 and 5.39% from P4. Most girls, 72.95%, had
 351 repeated a class level. Ninety-five per cent of the population were Christians with the remaining 5%
 352 Muslim. Of the sample, 83.07% had gone without food, water, medicine or school supplies in the
 353 past year. The mean score for symptoms using DASS-21 items was 12.66 (SD=6.48).

354 In multi-response option questions capturing all menstrual materials used at home during the last
 355 menstrual period: 58.10% of girls used disposable pads, 32.03% reusable pads, 19.93% cloth, 13.22%
 356 used their underwear alone, 7.64% toilet paper, 7.26% cotton wool and 5.40% used mattress and
 357 other materials. A total of 291 girls (54.49%) washed and reused menstrual materials during their
 358 last period.

359 A total of 59.14% changed materials three or more times on their heaviest day. Materials were
 360 changed in a bedroom (52.42%), a bathroom (26.39%), latrine (19.89%) or outside (1.30%) when at
 361 home. Most girls, 87.71%, had changed materials away from home at least one day during their last
 362 period.

363 Item responses

364 The proportions of responses, and number of missing, for each item in the 54-item pool are
 365 presented in Table 1. Frequencies highlight the menstrual management challenges facing girls. They
 366 also show a lower proportion of girls using the 'often' response option. There was a low proportion
 367 of missing data across scale items, varying from 0.00%-4.46%.

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3 368 **Item reduction**
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5 369 We removed items fitting poorly with a parsimonious and theoretically plausible factor structure,
6 370 and with the objective of balancing length with coverage. This meant poorly loading items, and some
7 371 items that duplicated concepts and had high intercorrelations were removed. Excluded items, with
8 372 reasons, are presented in Supplementary Materials 1.

10 373 Notably for item reduction, only 27% of girls always felt comfortable to use the same location for
11 374 urination during their period as when they were not menstruating, with a lower 23% girls
12 375 comfortable at school (items 33 and 37). This casts some doubts regarding responses to the
13 376 subsequent items, item 34 and 38, wherein girls reported their worries that others would see their
14 377 menstrual blood after urination. It is unclear if this question can apply accurately to those who may
15 378 have avoided usual latrines during menstruation. In EFAs we found items 33 and 37, and items 34
16 379 and 38 loaded on their own factors. Two-item factors were not considered acceptable for the
17 380 measure and all four items were excluded.(32)

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383 Table 1. Full 54 item pool and participant responding (n=538)

No.	Item	Never %	Some-times %	Often %	Always %	Missing (n)
1	I was able to choose the menstrual materials I most wanted to use	14.95	39.44	6.92	38.69	3
2	My menstrual materials were comfortable	14.53	29.62	11.32	44.53	8
3	(r) I worried that my menstrual materials would allow blood to pass through to my outer garments	28.63	38.42	14.69	18.27	7
4	(r) I worried that my menstrual materials would move from place while I was wearing them	30.92	44.08	9.92	15.08	14
5	(r) I worried about how I would get more of my menstrual material if I ran out	23.56	43.87	13.41	19.16	16
6	I had enough of my menstrual materials to change them as often as I wanted to	18.73	33.59	11.58	36.10	20
7	I was satisfied with the cleanliness of my menstrual materials	13.42	23.15	13.04	50.39	24
8	I could get more of my menstrual materials when I needed to	19.35	41.18	13.09	26.38	11
9	I felt comfortable carrying spare menstrual materials with me outside my home	30.86	32.76	10.86	25.52	13
10	I felt comfortable carrying menstrual materials to the place where I changed them	30.12	30.69	11.39	27.80	20
11	I felt comfortable transporting used materials to wash or dispose of them	22.81	31.18	12.74	33.27	12
12	I had a clean place to store my menstrual materials when I was not using them during my period	12.69	23.11	10.42	53.79	10
13	(r) I was worried that someone would see my stored menstrual materials when I was not using them	24.95	44.47	10.32	20.26	5
14	I felt comfortable storing my menstrual materials until my next period	14.66	21.80	7.52	56.02	6
15	I was able to wash my hands <u>when</u> I wanted to	4.31	24.72	6.37	64.61	4
16	I was able to wash my vagina <u>when</u> I wanted to	10.53	16.35	10.71	62.41	6
17	I was able to wash my hands and vagina <u>as often</u> as I wanted to	9.33	20.19	12.00	58.48	13
18	(r) I was concerned that I would not have enough soap to wash my hands or vagina	19.77	46.90	12.98	20.35	22
19	I felt clean during my last period	13.02	25.09	13.09	47.92	8
20	(r) I worried about where to dispose of my used menstrual materials	36.55	30.49	11.93	21.02	10
21	(r) I worried that people, or animals, may be able to access my used menstrual materials after I disposed of them	44.03	30.22	9.89	15.86	2
22	(r) I was concerned that others would see my used menstrual materials in the place I disposed of them	33.02	38.81	12.31	15.86	2
23	I was able to immediately dispose of my used menstrual materials	15.46	26.07	11.73	46.74	1
24	I was able to dispose of my used materials in the way that I wanted to	21.00	19.89	11.90	47.21	0
25	When at home, I was able to change my menstrual materials <u>when</u> I wanted to	6.16	23.13	6.16	64.55	2
26	When at home, I was satisfied with the place I used to change my menstrual materials	8.07	23.45	12.38	56.10	5
27	When at home, I had a clean place to change my menstrual materials	5.69	18.41	11.76	64.14	11
28	(r) When at home, I worried that I would not be able to change my menstrual materials when I needed to	30.22	35.63	14.93	19.22	2
29	(r) When at home, I worried that someone would see me while I was changing my menstrual materials	30.58	41.65	8.82	18.95	5
30	(r) When at home, I worried that someone would harm me while I was changing my menstrual materials	46.60	26.76	9.81	16.79	8
31	(r) When at home, I worried that something else would harm me while I was changing my menstrual materials (e.g., animals, insects, unsafe structure)	47.96	32.34	8.36	11.34	0

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32	(r) When at home, I worried that someone would see me when I was washing my vagina	39.25	35.85	8.49	16.42	8
33	When at home, I felt comfortable using the same location for urination as when I do not have my period	37.27	25.84	9.93	26.97	4
34	(r) When at home, I worried that others would see my menstrual blood after I had urinated	29.66	38.43	9.70	22.20	2
35	When at school, I was able to change my menstrual materials <u>when</u> I wanted to	34.51	33.77	6.72	25.00	2
36	When at school, I was satisfied with the place I used to change my menstrual materials	29.06	30.19	12.08	28.68	8
37	When at school, I felt comfortable using the same location for urination as when I do not have my period	38.97	28.25	9.60	23.35	7
38	(r) When at school, I worried that others would see my menstrual blood after I had urinated	28.89	39.77	10.69	20.64	5
39	When at school, I had a clean place to change my menstrual materials	30.17	26.94	10.44	32.45	11
40	(r) When at school, I worried that I would not be able to change my menstrual materials when I needed to	23.21	41.51	13.02	22.26	8
41	(r) When at school, I worried that someone would see me while I was changing my menstrual materials	28.63	39.55	12.99	18.83	7
42	(r) When at school, I worried that someone would harm me while I was changing my menstrual materials	37.83	30.90	10.67	20.60	4
Items relevant to those washing and reusing materials (n=291)						
43	I had enough water to soak or wash my menstrual material	6.23	20.76	5.54	67.47	2
44	I had access to a basin to soak or wash my menstrual materials whenever I needed it	13.06	26.12	9.97	50.86	0
45	I was able to wash my menstrual materials <u>when</u> I wanted to	15.14	23.94	7.75	53.17	7
46	I had enough soap to wash my menstrual materials	8.80	31.34	9.51	50.35	7
47	(r) I worried that someone would see me while I was washing my menstrual materials	27.92	42.76	12.01	17.31	8
48	(r) I worried about how I would get soap to wash my menstrual materials	31.07	38.93	12.14	17.86	11
49	(r) I worried that my menstrual materials would not be dry when I needed them	31.49	39.10	13.49	15.92	2
50	(r) I worried that others would see my menstrual materials while they were drying	23.08	42.31	12.24	22.38	5
51	I was able to dry my materials <u>when</u> I wanted to	12.98	22.11	13.33	51.58	6
52	I was satisfied with the place I used to dry my menstrual materials	15.03	25.87	9.44	49.65	5
53	I was satisfied with the appearance of my menstrual materials after I had cleaned them	8.04	24.83	12.24	54.90	5
54	I was satisfied with the smell of my menstrual materials after I had cleaned them	21.80	25.26	7.27	45.67	2

384 (r) reverse scored.

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387 Dimensionality

388 EFA on the first random split-half of the data was undertaken, first for the items applying to all
389 respondents. This process concluded with a 28-item, four-factor solution explaining 80% of the total
390 variance. Factorability was confirmed through visual inspection of the polychoric correlation matrix,
391 and Kaiser-Meyer-Olkin (KMO) sampling adequacy of 0.72 for the final 28-item split-half sample.
392 Thirteen girls were missing more than two items on the final 28 core items that applied to all
393 respondents. These participants were excluded from subsequent analyses.

394 A separate EFA was undertaken in the sub-sample of participants who reported they had washed
395 and reused materials during their last period and answered questions concerning washing and
396 drying during the last period (n=286). A two-factor solution was retained, with a total of eight items
397 of the original 12. Factor structure and loadings are presented in Table 2.

398 EFA was followed by a CFA of the second split-half of the data for the 28 core items, and the entire
399 subset of those reusing materials for the additional 8 reuse items. The four-factor model was a good
400 fit for the data (RMSEA=0.028-0.029; CFI=0.961-0.964; TFI=0.957-0.959). In the initial EFA solution
401 two items (9 and 10) were cross loaded on home and school-related domains. This fit theoretically
402 with the data since these items did not specify a location. In CFA on the second split-half, these
403 items loaded more strongly on the school-factor and loaded poorly on the home-factor. These items
404 were retained under only the 'transport and school environment needs' factor. A final CFA on the
405 full data set supported good model fit for the core 28-items (RMSEA=0.028-0.029; CFI=0.957-0.959;
406 TFI=0.953-0.955), and the additional reuse items (RMSEA=0.021-0.030; CFI=0.987-0.994; TFI=0.981-
407 0.991).

408 The CFA on the full data set was compared to bi-factor and hierarchical models using structural
409 equation models (SEM). Neither a bi-factor (RMSEA=0.041; CFI=0.913; TFI=0.906) nor a hierarchical
410 model (RMSEA=0.051; CFI=0.877; TFI=0.855) were a better fit for the first imputed data set and were
411 not investigated further.

412 Model invariance in the full data set was assessed, comparing those exclusively using disposable
413 sanitary pad (n=191) to others (n=334). A model constraining both thresholds and loadings remained
414 an acceptable fit (RMSEA=0.029; CFI=0.948; TFI=0.947) supporting the generalisation of latent
415 constructs (subscales) across these two groups and suggesting that scores can be meaningfully
416 compared across those using different menstrual materials. Item 6, having enough materials to
417 change as often as desired, loaded more poorly when groups were separated (estimate=0.36) which
418 may indicate some variability in this question based on material type.

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421 **Table 2. Factor structure and loadings for split-half EFA, CFA, and full sample CFA**

Item Number	Split-half EFA (n=261)	Split-half CFA (n=264)	Full sample Final CFA (n=525)
Material and home environment needs			
2	0.46	0.62	0.53
6	0.45	0.52	0.45
7	0.62	0.58	0.62
8	0.38	0.54	0.49
9	0.36	-0.03	-
10	0.36	0.11	-
14	0.71	0.41	0.53
15	0.64	0.64	0.59
23	0.52	0.54	0.58
24	0.43	0.61	0.56
25	0.75	0.62	0.67
26	0.61	0.68	0.67
27	0.71	0.60	0.65
Transport and school environment needs			
9	0.27	0.63	0.58
10	0.25	0.47	0.58
35	0.55	0.60	0.60
36	0.65	0.63	0.62
39	0.76	0.66	0.64
Material reliability concerns			
3	0.63	0.51	0.53
4	0.31	0.51	0.54
5	0.57	0.55	0.52
Change and disposal insecurity			
20	0.40	0.49	0.48
22	0.49	0.61	0.57
28	0.47	0.50	0.50
29	0.31	0.54	0.52
30	0.72	0.78	0.72
31	0.50	0.66	0.64
40	0.62	0.46	0.48
41	0.54	0.51	0.53
42	0.54	0.66	0.57
Reuse items	Full-sample	(N/A)	Full sample
Item number	EFA (n=286)		CFA (n=286)
Reuse needs			
43	0.71	-	0.74
44	0.53	-	0.53
45	0.58	-	0.59
46	0.66	-	0.68
51	0.57	-	0.58
Reuse insecurity			
47	0.57	-	0.69
49	0.42	-	0.45
50	0.54	-	0.53

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3 424 **Scale scores and reliability**
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5 425 Subscale scores and total score were calculated as mean scores where never=0, sometimes=1,
6 426 often=2 and always=3 for positively coded items, and the reverse for negatively coded items. All
7 427 subscales have ranges from 0 to 3, and higher scores represent more positive experiences. Subscales
8 428 specific to those reusing materials were only calculated for this population. Total score included
9 429 reuse items for those to whom these were applicable. Plots showing relationships between the core
10 430 four factors, and the total score are displayed in Supplementary Materials 2.

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13 431 Cronbach's α , and ordinal α are presented in Table 3. Acceptable reliability was achieved for most
14 432 subscales. The two three-item subscales, material concerns and reuse insecurity, had poorer internal
15 433 consistency.

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17 434 Fifty-six girls completed the re-test survey. Of those, three were missing scores on MPNS items at
18 435 original survey, and one had more than two missing items on the retest. Test-retest reliability for the
19 436 52 participants with repeat data using single-measure ICC are displayed in Table 3. Reliability varied
20 437 meaningfully between girls we estimated to be reporting on the same menstrual period as the
21 438 original survey, compared to those who reported having a new period. We took the reliability among
22 439 the subsample of girls reporting on the same menstrual period (n=20) as indicative of scale reliability
23 440 as questions specifically ask about the last period.

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443 **Table 3. Scale scores, internal consistency, test-retest reliability, and interrelationships**

	Internal Consistency			Test-retest reliability ICC _(2,1) (95%CI)		Correlations between subscales (Pearson's r)					
	Mean (SD)	α	Ordinal α	Same period (n=20)	New period (n=32)	1	2	3	4	5	6
Total score (n=525)	1.82 (0.37)	0.77	0.82	0.69 (0.36-0.86)	0.30 (-0.05-0.58)	0.75	0.54	0.31	0.44	0.51	0.30
1. Material and home environment needs	1.99 (0.62)	0.79	0.84	0.53 (0.12-0.78)	0.46 (0.14-0.69)	1.00	0.51	-0.08	-0.15	0.65	-0.02
2. Transport and school environment needs	1.35 (0.78)	0.66	0.73	0.67 (0.33-0.85)	0.22 (-0.14-0.53)	-	1.00	-0.20	-0.24	0.43	-0.09
3. Material reliability concerns	1.81 (0.73)	0.51	0.55	0.24 (-0.22-0.61)	0.08 (-0.27-0.41)	-	-	1.00	0.43	-0.01	0.35
4. Change and disposal insecurity	1.87 (0.61)	0.74	0.80	0.56 (0.17-0.80)	0.16 (-0.20-0.48)	-	-	-	1.00	-0.15	0.50
5. Reuse needs (n=286)	2.08 (0.72)	0.66	0.76	n=12 0.67 (0.19-0.89)	n=17 0.72 (0.38-0.89)	-	-	-	-	1.00	0.06
6. Reuse insecurity (n=286)	1.78 (0.73)	0.47	0.56	-0.07 (-0.60-0.50)	0.23 (-0.26-0.63)	-	-	-	-	-	1.00

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447 **Validity**

448 Content validity of the scale was assessed through comparison with findings from qualitative
449 research, FGDs with enumerators undertaking surveys of menstrual hygiene, and survey of experts.

450 For construct validity, we tested predictive relationships between scale scores and confidence to
451 manage menstruation, school absenteeism, and mental health symptoms. Bivariate associations are
452 presented in Table 4. Fewer worries about material reliability and changing were associated with
453 fewer depression and anxiety symptoms. In contrast, positive perceptions of material, home and
454 school environment needs were weakly associated with mental health.

455 More positive perceptions of materials, home and school environments predicted significantly
456 higher odds of feeling confident to manage menstruation at home or school. Supporting item
457 validity, positive school assessment was not associated with confidence at home. Material and home
458 environments did show a weaker, but positive relationship with school management confidence,
459 however this subscale includes items regarding menstrual materials and disposal which are likely to
460 cross settings. Fewer concerns about material reliability, insecurity in changing and disposal access
461 across contexts, and more positive perceptions of materials and home environments were
462 associated with higher odds of attending school during menstruation. A higher MPNS total score,
463 which captures girls' perceptions across all practices and environments, predicted much higher odds
464 of confidence to manage menstruation and attending school during menses.

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466 **Table 4. Bivariate associations between scale scores and hypothesised correlates**

		Material and home environment	Transport and school environment	Material reliability concerns	Change and disposal insecurity	Total
		<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)
DASS-21 total score ¹ (n=518)		0.04 (<i>p</i> =.333)	0.16 (<i>p</i> <.001)	-0.27 (<i>p</i> <.001)	-0.26 (<i>p</i> <.001)	-0.11 (<i>p</i> =.013)
	%	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Felt confident to manage menstruation at home ²	80.92	2.87 (1.99,4.15)	1.25 (0.94,1.67)	1.09 (0.81,1.47)	0.92 (0.64,1.31)	4.09 (2.14,7.81)
Felt confident to manage menstruation at school	51.72	1.97 (1.47,2.63)	1.94 (1.53,2.45)	1.14 (0.90,1.44)	1.05 (0.80,1.39)	4.22 (2.52,7.06)
Does not usually miss school during menstruation	61.90	1.48 (1.11, 1.97)	1.14 (0.91,1.43)	1.28 (1.00,1.63)	1.33 (1.00,1.77)	2.52 (1.52,4.17)
Did not miss school during last menstrual period	69.25	1.11 (0.82,1.50)	0.99 (0.78,1.26)	1.54 (1.19,2.00)	2.10 (1.51,2.91)	2.62 (1.52,4.50)

467 ¹ DASS score ranges from 0-42, higher scores indicate greater anxiety and depression symptoms. ² not

468 confident = 1.00

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DISCUSSION

The Menstrual Practice Needs Scale (MPNS-36) is a self-report measure to evaluate the extent to which an individuals' menstrual management practices and environments are perceived to meet their needs. Development was informed by past research, including review of qualitative and quantitative studies, and expert input.(3, 16, 17, 33) The final tool reflects experiences across a range of practices. Emergent factors were theoretically plausible and translated into interpretable subscales. The MPNS demonstrated good internal consistency, and acceptable test-retest reliability. Associations with hypothesised correlates supported the validity of the measure and its use in future research.

We hypothesised a-priori that emergent factors would reflect groups of practices, and that appraisals of environments would load on separate factors. Hypotheses were partially supported. The final four-and two-factor structure separated girls' appraisals of the reliability of their menstrual materials, home, and school environments. However, items capturing worries and concerns about changing environments, disposal and materials, loaded separately from ratings of comfort, satisfaction and adequacy of practices. These factors were not strongly correlated, or in the case of 'transport and school environment needs' and 'change and disposal insecurity', showed a small to modest negative correlation. Taken together, relationships suggest that greater satisfaction and comfort with menstrual practices does not translate into fewer worries about their reliability or risks to privacy or safety. Appraisals of privacy needs may be more strongly dictated to by internalised menstrual stigma, social relationships and norms, independent of the acceptability and comfort of other practices. Inspection of bivariate correlations suggested that trade-offs may be made between the favourability of the location to change menstrual materials and the accessibility of disposal options, contributing to negative subscale correlations. The use of 'worries' terminology in scale items was selected to best align with past qualitative reports and to prevent confusion which may arise in positively and negatively worded items using the same response options.(3, 34) However, we acknowledge this may have been more likely to evoke anxieties than items asking about 'comfort' or having 'enough' of various resources. Feedback from enumerators suggested that girls in this study did not struggle with the nature of these items as the response options were in the affirmative direction for all questions. Enumerators did report that a measure included for validation, the Rosenberg Self-Esteem Scale,(35) which included positively and negatively worded items through use of alternate wording like "I do" versus "I do not" with the same response options caused difficulties for respondents. There was no such evidence of difficulties with reverse coded items in the MPNS-36 in enumerator feedback, frequencies, or visual inspection of surveys. Future research is needed to further investigate the interrelationships between menstrual needs, insecurities, and how females make menstrual practice decisions.

Measuring women's and girls' menstrual practice needs involves gaining an understanding of the acceptability, comfort, reliability of practices and insecurities around privacy, safety and exposure of menstrual status. Drawing on this theoretical underpinning, and the relatively acceptable performance of bi-factor and hierarchical models including a total score, we would argue that a total score capturing perceptions across the range of practice and environmental needs is appropriate. This score is likely to be of use to researchers and practitioners, summarising experience across the breadth of behaviours. Subscale and total scores were calculated using mean scores rather than factor scores. Mean scores allow for correction of single missing data points, by averaging across other items, and are accessible for practitioners who may not have access to the statistical packages needed to calculate factor scores. Since much of the data on menstrual experiences is collected as

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3 515 part of NGO monitoring and evaluation, comparability across these data and that in research studies
4 516 is valuable so we suggest researchers use mean scores.

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6 517 Insecurities about the privacy and safety of the locations used to change menstrual materials loaded
7 518 on the same factor for questions concerning home and school environments. It is important to note
8 519 that this indicates that these ratings co-varied, not that change locations in these settings were given
9 520 the same ratings. School environments received much more negative appraisals, captured through
10 521 frequencies and means. For research or practice evaluation that focuses on either home or school
11 522 environments, the separate appraisal of location-specific subscales may need to be validated.
12 523 However, further investigation is needed as covariation of home and school privacy ratings could
13 524 suggest interdependencies between the two. It is plausible that experiences and learned
14 525 expectations from home environments influence perceptions of school environments. Changes to
15 526 individuals' expectations for their menstrual experience in response to interventions was an
16 527 overarching theme of a recent meta-synthesis of qualitative studies of menstrual health
17 528 interventions and would fit with this interpretation of our findings.⁽³⁶⁾ Alternatively, a joint
18 529 predictor, such as internalised stigma, may contribute to both appraisals. This should be explored in
19 530 future research and may indicate the need to assess both location responses even if interventions
20 531 only focus on school infrastructure.

25 532 **Strengths and limitations**

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27 533 Development of items drawing on the experiences of women and girls across low- and middle-
28 534 income countries through systematic review indicates the potential for the MPNS-36 to be relevant
29 535 across contexts. This approach was undertaken at the cost of specificity for the pilot population. A
30 536 measure developed through qualitative study of the Soroti schoolgirl population may have yielded a
31 537 different prioritisation of items. However, we were mindful of the ongoing measurement needs
32 538 across contexts and calls for improved comparability, particularly across trial studies.^(5, 8) At the
33 539 same time, piloting and validation was undertaken in a single context and the measure should be
34 540 evaluated in other languages and settings. Feedback from FGDs with enumerators in Niger, and
35 541 online survey of experts suggest some languages or contexts may favour a 3-point response scale.
36 542 Adapted response options as "less than half the time" and "more than half the time" may be more
37 543 specific replacements for "sometimes" and "often" depending on the language of the scale. Our
38 544 validation was limited by the lack of past quantitative research on predictive relationships between
39 545 menstrual experience and outcomes, and the absence of other measures against which to assess
40 546 convergent or divergent validity.

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44 547 Some items asked of all respondents may not be applicable. For example, those who avoid school
45 548 during menstruation were still asked about cleanliness, privacy and safety concerns and may report
46 549 fewer worries as they manage their needs by avoiding changing materials at school. For simplicity,
47 550 we recommend not using additional filters to questions, however response patterns should be
48 551 explored in future studies and through cognitive interviewing, particularly where the measure is
49 552 used in intervention studies.

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52 553 As noted in methods, item reduction drew on factor analysis, but also considered the need for
53 554 content validity through the coverage of different menstrual practices. We also prioritised brevity.
54 555 Decisions to remove some items, such as those that were felt to duplicate practices may have
55 556 reduced the internal consistency metrics of the scale but ensured items represented the breadth of
56 557 practice experiences. Two subscales of three items each, 'material reliability concerns' and 'reuse
57 558 insecurity' did not achieve acceptable internal consistency or test-retest reliability. This is likely due
58 559 to the small number of items and variability within the short set. We retained these as separate

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3 560 subscales as we recognise concerns about the performance of menstrual materials and worries
4 561 about exposure during washing and drying are salient parts of menstrual experiences.(3, 12)
5 562 Additional or refined items tested in future studies may improve the reliability of these subscales.

7 563 Test-retest reliability was assessed in a small sub-sample of participants. This sample size was
8 564 reduced further due to the differential reliability between those reporting on the same menstrual
9 565 period as their original survey. These data raise questions regarding the variability of menstrual
10 566 experiences. Findings could also suggest that participating in the survey made girls more attentive to
11 567 their needs during subsequent periods, leading to a change in their appraisals, a possibility that
12 568 should be explored in subsequent studies and larger samples.

15 569 **Implications for research and practice**

17 570 Quantitative study of menstrual experiences has focused on measures of menstrual practices.
18 571 Practices warrant investigation, however, increasingly menstrual health programming and policy
19 572 have recognised that individuals and communities vary in their preferences and the practices viewed
20 573 as preferable or acceptable.(37) The MPNS-36 prioritises participant perceptions of adequacy above
21 574 researcher-defined 'adequate' menstrual practices. Although the definition of menstrual hygiene has
22 575 evolved, the measure also provides an assessment of self-perceived menstrual hygiene status.

25 576 To date, research has relied on single practices, typically use of sanitary pads, to test associations
26 577 between menstrual health and hypothesised consequences on school absenteeism or wellbeing.
27 578 Such analyses fail to incorporate the range of practices needed for menstrual management, and
28 579 poorly translate the findings from qualitative research into quantitative research questions. The
30 580 MPNS-36 offers a way to test relationships between overarching menstrual practice experience and
31 581 education, health, wellbeing and social participation consequences in cross-sectional or longitudinal
32 582 studies. The measure could be applied in needs assessments or NGO monitoring and evaluation. The
33 583 MPNS-36 could be used in trials of menstrual health interventions to assess how programs change
34 584 practice experiences and would likely represent a key mediating assumption between interventions
35 585 such as product provision or sanitation improvements, and end line impacts such as school
36 586 attendance. Further studies will be needed to test the association between practice needs as
37 587 measured through the MPNS-36 and school attendance, triangulating self-report data with more
38 588 reliable methods such as school spot-checks.

41 589 Although the tested scale specified school as the location for a subset of items, this wording could be
42 590 adapted to the workplace, or when 'away from home' when applied to adult or out-of-school
43 591 samples. These groups require more attention,(3) and investigation of scale performance in these
44 592 populations would be of value.

47 593 In sum, the menstrual practice needs scale is a self-report measure specifically developed to assess
48 594 the extent to which an individuals' menstrual management practices and environments are
49 595 perceived to meet their needs. The final instrument has high face validity, reflecting experiences
50 596 across a range of practices and the total and subscale scores could be useful in needs assessment,
51 597 monitoring and exploring intervention impact.

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599 **Ethical approvals**

600 All girls provided signed assent to participate. Parents were informed about the study through
601 parent-teacher meetings at each school, teacher contact with parents, and information sheets in
602 English and Ateso sent home with girls prior to the study. Parents were asked to contact the school
603 or study staff if they did not consent to daughters' participation, or express concerns during parent-
604 teacher meetings. No parents expressed concerns about the study and no girls declined
605 participation.

606 Ethical approval was provided by Johns Hopkins School of Public Health Institutional Review Board
607 (IRB approval no: 00009073), and the Mildmay Uganda Research Ethics Committee (MUREC)
608 (approval ref: 0212-2018). The Uganda National Council for Science and Technology (UNCST)
609 approved the study (ref: SS279ES). Feedback on draft measure items by experts through online
610 survey and focus group discussions of resident enumerators in Niger were exempted from ethical
611 review by the Johns Hopkins School of Public Health Institutional Review Board. Participants of these
612 consultations consented to participate.

613 **Patient and Public Involvement**

614 This manuscript reports on the development and validation of a measure of menstrual practice
615 needs. Potential users of the measure, researchers and NGO practitioners, were included in the
616 research process through an expert survey to solicit feedback on the measure. Further, we
617 undertook focus group discussions with data collection staff to engage their feedback. Patients/the
618 public were not involved in the study design. Dissemination of this work was developed with
619 collaboration from the implementing partner NGO, Irise Institute East Africa.

620 **Acknowledgements**

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622 assistants who undertook data collection. We thank Dr Christian van Engers for developing the code
623 for visual representation of the data in Supplementary Materials 2 and the administration of the
624 www.menstrualpracticemeasures.org website. We are grateful to Prof. G.J. Melendez-Torres for his
625 statistical guidance. We are indebted to the numerous experts in menstrual health who took the
626 time to review draft items and provide their insights.

627 **Funding**

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629 **Contributions**

630 JH designed the study, undertook analysis, interpretation, and wrote the first draft of the
631 manuscript. AN, CS, MR, KS, AA, contributed to study design, interpretation, and critically reviewed
632 the manuscript. MR critically reviewed measure materials and analytic strategy. AN coordinated data
633 collection and implemented study protocols. AA facilitated translation and back-translation of survey
634 tools, supported data collection and feedback on the performance of items. All authors have
635 approved the final manuscript.

636 **Data sharing statement**

637 Deidentified data is available from: <https://osf.io/qshkc/>. The final MPNS-36 measure and scoring
638 information is available online from www.menstrualpracticemeasures.org

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3 640 **Competing interests**
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5 641 Calum Smith works for Irise International, an organisation dedicated to creating a world where all
6 642 women and girls can reach their full potential, regardless of their periods. Irise International receives
7 643 funding from various sources to develop school-based menstrual health interventions in East Africa
8 644 and from Sustain for Life to work with schools in Soroti, Uganda. Agnes Nansubuga and Agnes Akullo
9 645 work for Irise Institute East Africa, a local implementing partner of Irise International.

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11
12 646 JH, MR, KJS declare no competing interests.
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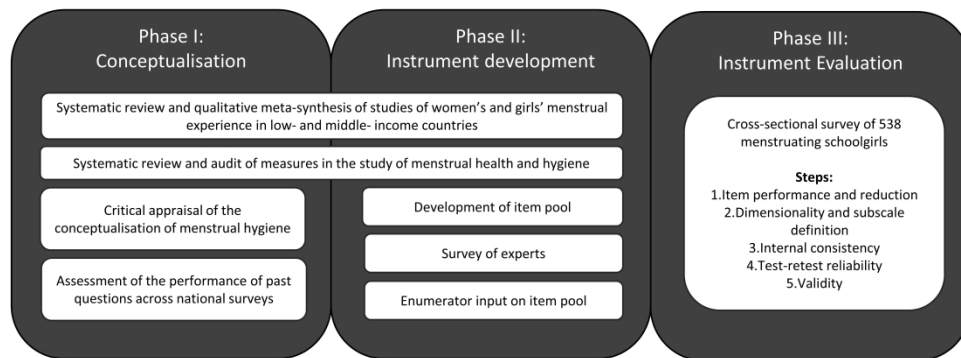


Figure 1. Phases of development of the MPNS-36

239x92mm (600 x 600 DPI)

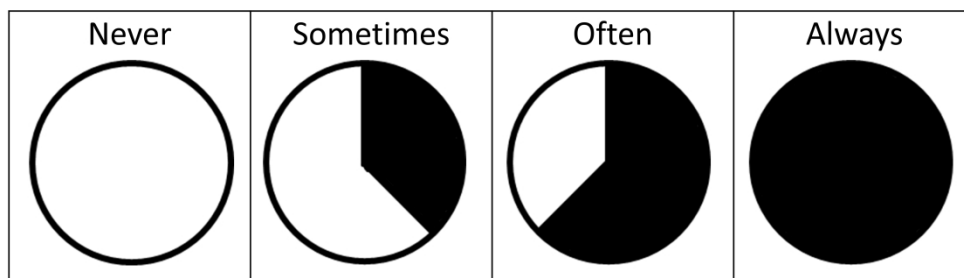


Figure 2. Visual chart for MPNS item response options

243x75mm (600 x 600 DPI)

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Supplementary Materials 1

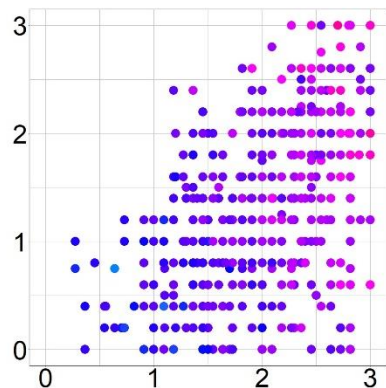
Removed items with reasons for removal

No.	Item	Reasons for removal
1	I was able to choose the menstrual materials I most wanted to use	Removed for scale length and balance of materials-focused items, represented by other items
11	I felt comfortable transporting used materials to wash or dispose of them	Low loading (0.28), better represented by 9 and 10.
12	I had a clean place to store my menstrual materials when I was not using them during my period	Cross-loaded negatively with material reliability concerns (-0.39). Storage captured by item 14.
13	(r) I was worried that someone would see my stored menstrual materials when I was not using them	Poor loading in initial EFA. Some cross-loading with urination items (33, 37). Storage remains captured by item 14.
16	I was able to wash my vagina <u>when</u> I wanted to	Items 15, 16, 17 all loaded highly on material and household facility needs factor and were highly correlated with one another. 16 removed for length and focus on menstrual experience.
17	I was able to wash my hands and vagina <u>as often</u> as I wanted to	Removed as above, and for cross-loading with material reliability concerns (-0.38)
18	(r) I was concerned that I would not have enough soap to wash my hands or vagina	Poor loading and removed for length. Focus on menstrual-specific concerns prioritised.
19	I felt clean during my last period	May reflect internalized stigma more than experience of hygiene/menstrual practices. Viewed as value-laden and removed.
20	(r) I worried about where to dispose of my used menstrual materials	Removed for length, items 22, 23, 24 concern disposal.
21	(r) I worried that people, or animals, may be able to access my used menstrual materials after I disposed of them	Removed for length and to reduce number of disposal items, represented by 22.
32	(r) When at home, I worried that someone would see me when I was washing my vagina	Removed for length and to maintain focus on menstrual experience rather than broader washing. Loaded with other privacy concerns. Small cross-load with household facilities (0.20).
33	When at home, I felt comfortable using the same location for urination as when I do not have my period	Urinating in the same location loads with home and school urination items, but not well with other items, poor pairwise correlation with other items except urination items. Remove for scale parsimony.
34	(r) When at home, I worried that others would see my menstrual blood after I had urinated	If many girls do not use latrines when menstruating this question likely to poorly differentiate (those not worrying may be those avoiding usual locations). Loads with school-based urination item.
37	When at school, I felt comfortable using the same location for urination as when I do not have my period	As for 33.
38	(r) When at school, I worried that others would see my menstrual blood after I had urinated	Removed as for item 34, differential responding based on location use and poor loading.
Items relevant to those washing and reusing materials		
48	(r) I worried about how I would get soap to wash my menstrual materials	Excluded for poor loading in EFA.
52	I was satisfied with the place I used to dry my menstrual materials	Removed for scale length.
53	I was satisfied with the appearance of my menstrual materials after I had cleaned them	Rated poorly by FGDs with enumerators in Niger. Concerns of shaming or respondents not answering honestly.
54	I was satisfied with the smell of my menstrual materials after I had cleaned them	
(r) reverse coded		

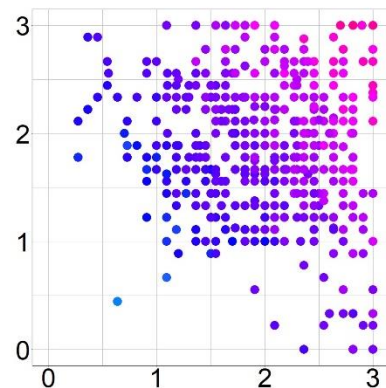
Supplementary Materials 2

Relationship between subscale scores (x axis, y axis) and total MPNS score (colour)

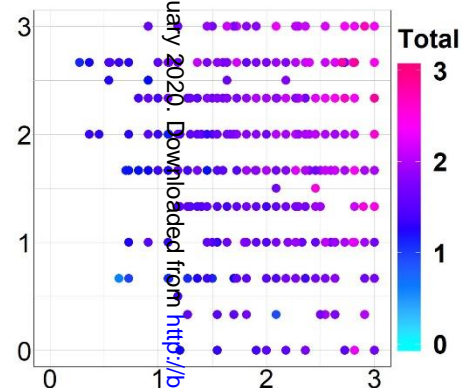
Material and home environment needs
and
Transport and school environment needs



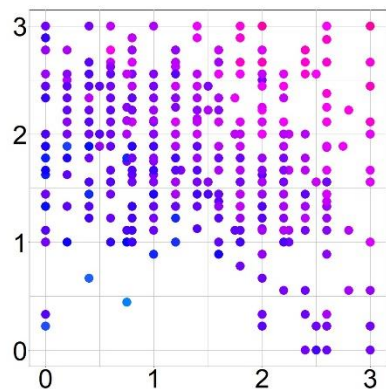
Material and home environment needs
and
Change and disposal insecurity



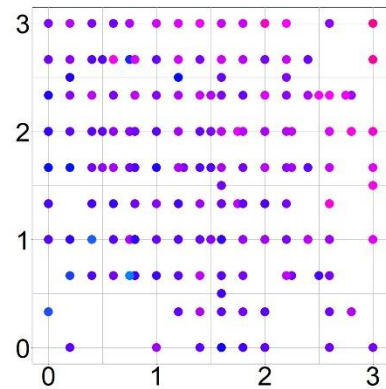
Material and home environment needs
and
Material reliability concerns



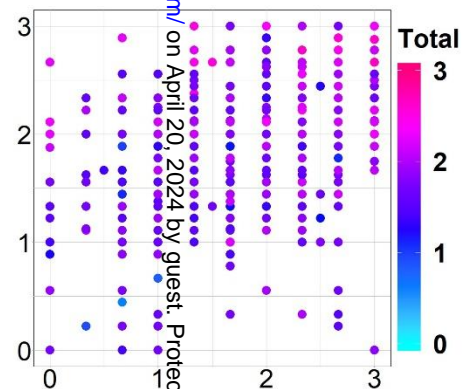
Transport and school environment needs
and
Change and disposal insecurity



Transport and school environment needs
and
Material reliability concerns



Material reliability concerns
and
Change and disposal insecurity



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Supplementary Materials 1

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Title
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction (pg. 4-5)
Objectives	3	State specific objectives, including any prespecified hypotheses	Scale development, Introduction Paragraph 6
Methods			
Study design	4	Present key elements of study design early in the paper	Abstract + Methods "Instrument evaluation"
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Method, "Instrument evaluation" Paragraph 1
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	"Instrument Evaluation" Paragraph 2-4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	"Survey content and question format"
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	"Survey content and question format"
Bias	9	Describe any efforts to address potential sources of bias	Instrument evaluation: Analyses
Study size	10	Explain how the study size was arrived at	"Study sample and data collection" Paragraph 1.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	"Instrument evaluation: Analyses" (starts page 9)
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Instrument evaluation: Analyses
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	Instrument evaluation: Analyses
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	Instrument evaluation: Analyses

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results – “Participants”
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results – “Participants”
		(b) Indicate number of participants with missing data for each variable of interest	Results “Item responses”
Outcome data	15*	Report numbers of outcome events or summary measures	Table 4
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	“Dimensionality” “Reliability” “Validity”
		(b) Report category boundaries when continuous variables were categorized	NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	“Dimensionality” “reliability”
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion, paragraph 1-3
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion – “Strengths and Limitations”
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussions – “Implications for research and practice”
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion “Strengths and Limitations”
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding statement (pg. 22) and journal submission system.

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Measuring menstrual hygiene experience: Development and validation of the Menstrual Practice Needs Scale (MPNS-36) in Soroti, Uganda

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-034461.R1
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Date Submitted by the Author:	10-Jan-2020
Complete List of Authors:	Hennegan, Julie; Johns Hopkins University Bloomberg School of Public Health, Environmental Health and Engineering Nansubuga, Agnes ; Irise Institute East Africa Smith, Calum; Irise International Redshaw, Maggie; NPEU, Department of Population Health Akullo, Agnes; Irise Institute East Africa Schwab, Kellogg; Johns Hopkins University Bloomberg School of Public Health, Environmental Health and Engineering
Primary Subject Heading:	Global health
Secondary Subject Heading:	Public health
Keywords:	menstrual hygiene, menstrual health, psychometrics, validation studies, outcome assessment

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8 3 **Measuring menstrual hygiene experience: Development and validation of the**
9 4 **Menstrual Practice Needs Scale (MPNS-36) in Soroti, Uganda**
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18 Julie Hennegan¹ (ORCID: 0000-0003-2011-1595)

19 9 Agnes Nansubuga²

20 10 Calum Smith³

21 11 Maggie Redshaw⁴

22 12 Agnes Akullo²

23 13 Kellogg J. Schwab¹ (ORCID: 0000-0002-4966-8517)
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25
26
27
28 14

29
30 15 ¹ The Water Institute, Department of Environmental Health and Engineering, Johns Hopkins
31 16 Bloomberg School of Public Health, Baltimore, MD, USA

32 17 ² Irise Institute East Africa, Jinja, Uganda

33 18 ³ Irise International, Sheffield, UK

34 19 ⁴ National Perinatal Epidemiology Unit (NPEU), Nuffield Department of Population Health, University
35 20 of Oxford, Oxford, UK
36
37 21
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40
41 23

42
43 24 Words: 6,881
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45 25

46 26 Correspondence:

47 27 Dr. Julie Hennegan

48 28 Johns Hopkins Bloomberg School of Public Health

49 29 615 N Wolfe St

50 30 Baltimore MD 21205

51 31 United States

52 32 jhenneg1@jhu.edu

53 33 Twitter: [julie_hennegan](https://twitter.com/julie_hennegan)
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ABSTRACT

Objectives. This study describes the development and validation the Menstrual Practice Needs Scale (MPNS-36) which measures the extent to which respondents' menstrual practices and environments meet their needs.

Methods. A 54-item pool was developed following systematic-review of qualitative and quantitative studies and expert feedback. Item reduction and scale validation were undertaken using a cross-sectional survey of 538 menstruating schoolgirls in Soroti, Uganda. Test-retest reliability was assessed in a sub-sample of 52 girls two weeks after the first administration. Construct validity was tested through relationships with hypothesised correlates: confidence to manage menses, self-reported school absenteeism, and mental health symptoms.

Results. The MPNS-36 comprises 28 items applicable to all respondents, and 8 items capturing washing and drying experiences for those reusing menstrual materials. A four-factor solution for the core 28 items was the best fit for the data (RMSEA=0.028-0.029; CFI=0.961-0.964; TFI=0.957-0.959), supplemented by two factors for reuse (RMSEA=0.021-0.030; CFI=0.987-0.994; TFI=0.981-0.991). Subscale and total scores were calculated as mean scores to support accessibility for practitioners. Subscales were 'material and home environment needs' (11 items, $\alpha_{\text{ordinal}}=0.84$), 'transport and school environment needs' (5-items, $\alpha_{\text{ordinal}}=0.73$), 'material reliability concerns' (3-items, $\alpha_{\text{ordinal}}=0.55$), 'change and disposal insecurity' (9-items, $\alpha_{\text{ordinal}}=0.80$), 'reuse needs' (5-items, $\alpha_{\text{ordinal}}=0.76$), and 'reuse insecurity' (3-items, $\alpha_{\text{ordinal}}=0.56$). Relationships between subscales and hypothesised correlates supported validity. Home- and school-based items were more strongly associated with confidence to manage menstruation at home and school, respectively. Higher total scores indicated more positive experiences, and were associated with greater odds of not missing school during the last menstrual period (OR=2.62, 95%CI=1.52-4.50). Test-retest reliability was moderate (total score: $\text{ICC}_{(2,1)}=0.69$).

Conclusions. The MPNS-36 demonstrated acceptable reliability and validity. It is the first measure to capture perceived menstrual hygiene and may be useful across a range of study designs. Future research should explore the validity and suitability of the measure across contexts and populations.

Keywords: menstrual hygiene; menstrual health; psychometrics; validation studies; outcome assessment

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3 68**Strengths and Limitations of this Study**4
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- This study reports the development and validation of the Menstrual Practice Needs Scale (MPNS-36) and the conceptual justification for the measure

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- Measure development drew on systematic reviews, and findings from studies of measurement challenges in menstrual health research across a range of contexts

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- The MPNS-36 sought to measure the degree to which the practices and environments used in managing menstrual bleeding meet respondents' needs.

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- There were no existing validated measures of menstrual experience against which to demonstrate convergent and divergent validity of the scale

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- The scale was tested among schoolgirls in Uganda, a single population and language, and requires further research on cross-cultural validity and use in other populations

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INTRODUCTION

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5 84 Reports of women's and girls' negative experiences of menstruation have led to an increasing
6 85 momentum to enact policies and programs to improve menstrual health.(1, 2) A growing body of
7 86 qualitative studies have described the challenges faced during menstruation and their implications
8 87 for female health and social participation.(3, 4) Qualitative methods are well-suited to capturing the
9 88 nuances of menstrual experience. However, quantitative studies are often needed to support
10 89 decision making, evaluate interventions, and monitor progress. To date, quantitative studies have
11 90 struggled to engage with the complexity of menstrual experiences and have been limited by the lack
12 91 of available measures to capture core concepts.(5) Researchers have relied on study-based
13 92 questionnaires in the absence of evidence to direct question selection or provide insights on
14 93 measure reliability and validity.

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18 94 This study reports on the development and validation of a new measure to capture respondents'
19 95 perceptions of their menstrual management needs. Here we describe: the identification of the
20 96 constructs targeted for assessment, the development of the Menstrual Practice Needs Scale (MPNS),
21 97 and the pilot and validation of the measure in a sample of menstruating schoolgirls in Soroti,
22 98 Uganda.

99 **Menstrual practice needs**

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26 100 Establishing ways to measure menstrual hygiene has been an ongoing gap and research priority in
27 101 the study of menstrual experience and interventions.(6-8) Good menstrual hygiene was initially
28 102 defined as "*women and adolescent girls using a clean menstrual management material to absorb or*
29 103 *collect blood that can be changed in privacy as often as necessary for the duration of the*
30 104 *menstruation period, using soap and water for washing the body as required, and having access to*
31 105 *facilities to dispose of used menstrual management materials.*"(9) This highlighted females' physical
32 106 management of menses.(10-12) The term has since seen new iterations, drawing in other menstrual
33 107 needs including knowledge of the menstrual cycle and supportive socio-cultural environments free
34 108 from stigma and menstrual-related restrictions.(12-14) To capture these varied aspects, multiple
35 109 indicators with specific methods of assessment will be necessary. While the formal definitions of
36 110 menstrual hygiene and menstrual health continue to evolve, the need for measures capturing the
37 111 implicit core concepts remains unchanged.(8)

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41 112 To inform our measure development efforts, we undertook a systematic review and meta-synthesis
42 113 of extant qualitative studies of women's and girls' menstrual experiences in low- and middle-income
43 114 countries (see (3)). We synthesised findings from 76 eligible studies to identify salient themes and
44 115 their relationships, developing an integrated model of menstrual experience. Of the identified
45 116 components of menstrual experience emerging from the review, two focused on women's and girls'
46 117 physical management of menstrual bleeding; menstrual practices, and perceptions of menstrual
47 118 practices and environments.(3) In describing the former, authors of included studies highlighted the
48 119 range of practices undertaken to manage menses, often discussing the ways practices influenced
49 120 discomfort or health. In the review we highlighted the distinction between these behavioural
50 121 practices such as the type of material used, and individuals' perceptions of practices adequacy,
51 122 comfort, or reliability. Perceptions reflected individual preferences and past experiences, resources,
52 123 knowledge, expectations and the norms of their socio-cultural environments.

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56 124 Quantitative study of menstrual experience has frequently collected data on individuals' menstrual
57 125 practices.(7) We would argue that practices alone are not well placed to capture individuals'
58 126 satisfaction or concerns, a frequent target for improvement in menstrual health programs. Measures

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3 127 assessing the type of material used do not reveal if this material was preferred, just as those
4 128 capturing the quantity of materials used do not indicate if the user felt this was sufficient. Practices
5 129 may be classified as more favourable based on their associations with reproductive tract
6 130 infections,(15) but the usefulness of these categories is limited when considering program impacts
7 131 on other outcomes such as menstrual experience, psychosocial wellbeing or social participation. We
8 132 hypothesise that measures of individuals' perceived adequacy of practices and environments are
9 133 likely to more closely align with findings from qualitative research and predict social participation
10 134 and wellbeing, as they acknowledge that the same practices may be appraised differently due to a
11 135 range of individual and sociocultural influences. We propose that quantitative assessment should
12 136 include measures of women's perceptions along with their practices. Both approaches align with the
13 137 existing description of menstrual hygiene, which does not specify whether adequate materials,
14 138 disposal, cleanliness, or privacy are defined by investigators through top-down appraisal of
15 139 behaviours or defined by respondents' perspectives.

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20 140 Thus, in this study we aimed to develop a measure that can capture the extent to which
21 141 respondents' current menstrual management practices and environments are perceived to meet
22 142 their needs. We restrict the measure to the practices undertaken and environments used to manage
23 143 menstrual bleeding; hypothesising that different measures will be needed to address other
24 144 constructs relating to menstrual pain or knowledge which are outside the scope of this work. To test
25 145 construct validity, we hypothesised that more positive perceptions of menstrual practices, that is,
26 146 reporting menstrual practice needs are being met, would be associated with lower school
27 147 absenteeism due to menstruation, higher confidence to manage menstruation, and fewer mental
28 148 health symptoms, based on past qualitative research.(3)

31 149 **Measurement considerations**

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33 150 MPNS development was informed by past research highlighting considerations for measurement
34 151 and preliminary investigations by our study team. First, past research has indicated that inadequate
35 152 attention to the full range of menstrual practices may provide a skewed appraisal of community
36 153 needs.(16) Measures focused on a subset of menstrual practices, such as the type of material used,
37 154 may lead to overemphasis on this aspect at the expense of others. The breadth of practices included
38 155 in the MPNS was informed through systematic review of past research.(3) Practices identified for the
39 156 measure were: menstrual materials used, frequency of changing materials, transportation and
40 157 storage of materials, handwashing during menstrual management, genital and body cleaning,
41 158 disposal of used materials, and methods of washing and drying materials, including access to a vessel
42 159 for holding water and the use of soap. This list is consistent with an independent qualitative study
43 160 which aimed to identify the breadth of practice challenges in India, lending further support to this
44 161 broad coverage.(12) A second consideration was informed by a preliminary study investigating the
45 162 location-dependency of menstrual practices. Through a cross-sectional study in Bangladesh, we
46 163 found that schoolgirls' self-reported menstrual practices, such as the material used, varied between
47 164 home and school environments, as did their confidence to manage menses. These findings suggest
48 165 that self-report items with unclear locations may not adequately reflect the experiences researchers
49 166 are aiming to measure.(17) Third, in focus group discussions (FGDs) with enumerators who had
50 167 implemented Performance Monitoring and Accountability (2020) surveys(18) in Niger, participants
51 168 reported that survey respondents rarely immediately understood the intention of items asking
52 169 whether their menstrual environment was 'private' or 'safe'. Enumerators frequently provided
53 170 clarifications based on their own understandings; which also differed. Findings from FGDs suggested
54 171 that 'privacy' and 'safety' as stand-alone terms may not be amenable to cross-cultural adaptation
55 172 and translation. Similar issues with the interpretation of 'privacy' were reported in an independent

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3 173 field test of measures in Belize.(19) For questions aimed at capturing these concepts, we returned to
4 174 the qualitative studies from which they were drawn and identified worries about being seen,
5 175 exposed or harmed as origins of 'privacy' and 'safety' priorities. This approach aligned with a recent
6 176 measure of sanitation insecurity.(20) Finally, practitioners and researchers alike recognise the
7 177 sometimes contradictory requirements in wishing to best capture experiences and at the same time
8 178 moderate participant fatigue and survey length. Thus, the measure needed to balance length with
9 179 comprehensiveness.

12 180 In sum, grounded in past research we defined menstrual practice needs as a core construct for
13 181 measurement, and drew on past studies and preliminary research to guide item development.

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17 183 **METHODS**

19 184 The MPNS was developed across three phases, summarised in Figure 1.

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23 186 [Insert Figure 1 about here]

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26 188 **Figure 1.** Phases of development of the MPNS-36

28 189 **Conceptualisation**

30 190 In the first phase we identified constructs for assessment through systematic reviews of past
31 191 research, assessed the need for new measures, and collated insights from the performance of past
32 192 questions. This is described in the introduction.

34 193 **Instrument development**

36 194 Using our systematic review of qualitative studies, we collated the menstrual practices reported, and
37 195 illustrative quotations of participants' perceptions of their practices and environments. These were
38 196 included in the meta-synthesis report, see (3). We also utilised the full set of studies thematically
39 197 coded in Nvivo 12 during the review, to provide an extensive set of quotations from which to draw
40 198 scale items.

43 199 Following initial item generation, we undertook an online survey of experts. We invited members of
44 200 the *East and Southern Africa Menstrual Hygiene Research Network*, and experts attending past *MHM*
45 201 *in Ten*(21) meetings to participate. Twenty-three experts provided feedback on a selection of 19
46 202 MPNS draft items. Participants identified as researchers (52%), practitioners (12%), or both (36%).
47 203 Experts rated the usefulness of MPNS items and were invited to make comments. One item was
48 204 removed from the pool due to poor ratings. Experts were also consulted regarding the response
49 205 format with 68% endorsing a 4-point Likert option. A further 14% preferred a 3-point scale, with
50 206 others suggesting dichotomous responses or responses varied by context/language.

53 207 Sixteen items, professionally translated into French, were presented to resident enumerators
54 208 following collection of Performance Monitoring and Accountability (PMA) 2020 surveys in Niamey,
55 209 Niger. Items were presented as part of focus group discussions (FGDs) concerning the performance
56 210 of menstrual hygiene questions in PMA2020 surveys. Twenty resident enumerators from Niamey
57 211 provided feedback on the response options, with endorsement of a 4-point scale. During FGDs
58 212 enumerators indicated two potentially problematic items, suggesting that these were less likely to

213 be reported honestly by older adult women. These items were removed after piloting. During FGDs,
214 enumerators were asked for their impressions of what each item sought to capture. Their
215 interpretations matched our intentions for the items.

216 Feedback on items from enumerators in Niger, our local, female data collection team in Uganda, and
217 input from menstrual health experts supported the face validity of the scale. Final item wording was
218 refined during translation and back-translation of items and research assistant training for the
219 validation study in Uganda. Timeline constraints and restrictions on the number of visits allowed to
220 study schools meant cognitive interviews were not undertaken with the target population and
221 should be pursued in future studies.

222 **Instrument evaluation: Study sample and data collection**

223 The target sample size was based on ten participants per item, a 10:1 ratio.(22) A cross-sectional
224 survey was undertaken across 12 schools in Soroti, Uganda. Soroti is a regional urban centre in the
225 Teso sub-region of Eastern Uganda. Ugandan Demographic Household Survey (DHS) data from 2016
226 reports that 41.5% of the Teso region population places in the lowest national wealth quintile.
227 According to DHS, 39.2% of households had an observed hand washing location, 63.7% of females
228 had attended some primary school as their highest educational attainment.(23)

229 Schools recruited for the survey were already engaged with the partner NGO, Irise Institute East
230 Africa, were all government schools, and had been selected by the District Education Office as those
231 with the greatest need. Data were collected March-May 2019. Girls 12 years and older were
232 recruited from Primary (P) class levels P5-6, with expansion to P4 and P7 to achieve the required
233 sample size. In the previous year (October 2018), pupils in P6 received a menstrual education and
234 product (reusable sanitary pad) intervention. These students should have graduated to P7 by the
235 time of the survey. Grade repetition, school transfer, and the inclusion of some P7 students to
236 achieve the required sample meant some participants in this study had received an intervention 5-6
237 months prior to the survey.

238 Six female research assistants, local to the area, were trained to deliver the survey. Surveys were
239 completed in groups of no more than six girls to one research assistant. Research assistants read
240 survey questions in Ateso and in English where helpful (e.g., to highlight response options).
241 Participants marked their responses on paper copies of the survey which were in English. Research
242 assistants monitored group progress and were able to provide individual or group clarifications, or
243 repeat items, if requested. Verbal delivery of items was standardised through training and practice
244 exercises for research assistants. Group surveys lasted approximately 75-90 minutes and were
245 undertaken during the school day at times selected by schools to avoid disruption.

246 Girls needed to be present at school and were recruited by class. If more girls were available than
247 could be surveyed, participants were selected using a simple systematic sampling approach (every
248 third girl across desk rows, repeated until the maximum number was met). Schools had at least two
249 visits for data collection. Almost all menstruating girls in participating classes were sampled to
250 achieve the target sample size. Re-test participants were recruited during the first data collection
251 visit to the first 10 schools visited. One research assistant per visit was selected to consent her group
252 of up to 6 girls for re-test survey and recorded their names next to an ID number. A reserve group of
253 girls were also consented. Upon repeat visit, the target re-test group were sought, with substitutions
254 from the reserve group if needed.

255 Data were entered into Qualtrics survey system (www.qualtrics.com) by trained research assistants.
256 Fifty surveys, 9.29%, were entered twice for error screening. Data entry error rate was 1.59%.

257 Survey content and question format

258 All survey items were translated and back-translated with input from research assistants local to the
259 area.

260 *Demographics.* Participants self-reported their age, class level, religion and whether they
261 had repeated any school grades. Household resources were assessed using four items from the
262 Afrobarometer lived poverty index,(24) indicating how often, over the past year, girls went without
263 food, clean water, medicine and school supplies.

264 *Menstrual practices.* A suite of questions asked girls about their menstrual practices, that is,
265 the practices undertaken to manage menstrual discharge. These questions also formed part of the
266 concurrent development of a menstrual practices questionnaire (MPQ), which will be reported
267 elsewhere. Behaviours were reported for the last menstrual period, consistent with MPNS items. For
268 the present study, we used items capturing the menstrual materials used during the last period at
269 home, frequency of change of menstrual materials and location of material change.

270 *Last menstruation.* We asked girls to estimate the timing of their last menstrual period in
271 broad terms “I have my period now”, “last week”, “within two weeks”, “within three weeks”, “one
272 month” or “more than one month ago”. For girls undertaking the re-test survey, those selecting the
273 first two options were coded as reporting on a new period.

274 *MPNS item pool.* The 54 draft items were included in the participant survey. The items took
275 the form of a personal statement followed by response options “never”, “sometimes”, “often”, and
276 “always”. Response options were accompanied by a visual tool, see Figure 2. Participants had been
277 familiarized with Likert responding earlier in the survey for agreement and disagreement items. The
278 MPNS section of the survey was preceded by an activity. Research assistants had a large version of
279 the visual tool and asked participants to report as a group on the frequency of a variety of school
280 activities. For example, “How often do you have a lunch break during the school day?”, “How often
281 do you have tests at school?”. The activity allowed research assistants to engage students regarding
282 the selected response category. Of the draft items, 32 were framed as positive statements (e.g., “I
283 was able to choose the menstrual materials I most wanted to use”) and 22 as negative statements
284 (e.g., “I was concerned that I would not have enough soap to wash my hands or vagina”). Items were
285 posed such that responses were always in the same direction (that is, increasing frequency from
286 never to always). Negative statements were reverse coded for calculating scale scores. On each
287 page, participants were reminded that items referred to the last menstrual period. Those currently
288 menstruating could respond in reference to their current or most recent past period.

289

290 [Insert Figure 2 here]

291

292 **Figure 2.** Visual chart for MPNS item response options

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294 *Psychological symptoms.* Psychological health was assessed using a modified version of the
295 Depression, Anxiety, Stress Scale (DASS-21).(25) Although this measure has not been used with this
296 population, it has shown evidence for content, structural and content validity, studied in both clinical
297 and non-clinical groups (26) and used with adolescents.(27) The scale shows high-quality evidence
298 for bifactor structure, with a generalised negative emotional state dimension intended for use in this

study.(26) For length, we selected only the depression and anxiety subscales and one item was removed from each scale. We removed anxiety item “*I was aware of dryness of my mouth*”, and depression item “*I felt down-hearted and blue*” as these were perceived to present challenges for translation and use in this population. Language was simplified for translation and the younger age group, for example “*I couldn’t seem to experience any positive feeling at all*” was simplified to “*I couldn’t experience any positive feelings*”. Participants reported how often over the past week they experienced each statement in the list. Response options were simplified to: 0 “never”, 1 “sometimes”, 2 “often”, 3 “almost always”. For analysis we used a total score, with depression and anxiety items transposed onto a 7-point scale to reflect the original. Total scores could range from 0 to 42 with higher scores reflecting greater negative emotional states.

Confidence to manage menstruation. Girls reported on a 4-point Likert scale from “Strongly disagree” to “Strongly agree” their agreement with the statement “*I feel confident to manage my menstrual period at home*” and “*at school*”. This was accompanied with a note that managing menstruation means “*collecting materials, changing, washing drying and disposing of materials during your period*”. Dichotomous responses of “confident” (agree or strongly agree) and “not confident” (disagree or strongly disagree) were used for analyses.

School attendance. Participants self-reported if they “usually” missed school during menstruation, providing “yes” or “no” responses. For comparison, girls reported if they missed school during their last menstrual period “yes”, “no”, or “not applicable” if their last period did not fall during school time.

Instrument evaluation: Analyses

Analyses were undertaken using Stata 15 and R Version 3.6.0.

Item responses were investigated through descriptive statistics. We used random split-halves of the data to develop then test the emerging factor structure. Acknowledging the ordinal nature of the data, exploratory factor analysis (EFA) with principal axis factoring was undertaken using the polychoric correlation matrix using Stata 15. Factorability was confirmed through visual inspection of the polychoric correlation matrix, and Kaiser-Meyer-Olkin (KMO) sampling adequacy. We used scree plots, eigenvalues >1 (Kaiser criterion), and theoretical plausibility as criteria against which item reduction and final factor structure were determined. We anticipated a-priori that any emergent factors would be correlated, and specified oblique rotation, using *promax* with Kaiser normalisation. To maintain content validity, we prioritised coverage of menstrual practices before selecting items with the highest factor loadings during reduction. Items with loadings <0.30 were considered to have poor loading. During exploratory factor analysis we permitted cross-loading for two items which applied to both school and home settings. These were confined to a single factor in the final model.

We explored potential predictors of missing data including class level, age, and household resources and identified no pattern of missing data. Little’s MCAR (missing completely at random) test was non-significant $\chi^2=4107.57$, $p=0.246$, further supporting our assumption that there was no pattern. A total of 13 girls (2.4%) were missing more than 2 items on the final 28-core item measure and were excluded from final analysis. Missing data were deleted pairwise for EFAs.

We undertook confirmatory factor analysis (CFA) using the *lavaan* package in R.(28) Reflecting the ordinal nature of the data, we used a robust diagonally weighted least squares estimator (DWLS). DWLS requires complete data. As 26.86% of girls were missing 1 or 2 items on the 28-core item set, complete case analysis would have omitted too many participants. Multiple imputation using chained equations with the *mice* package in R (29) was undertaken, using a proportional odds model

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3 343 recognizing the ordered categorical nature of the variables and generating 10 imputed data sets.
4 344 This was considered sufficient, with small changes in factor loadings observed across imputations. As
5 345 *lavaan* does not support multiply imputed data with DWLS estimation, we extracted the ten imputed
6 346 data sets and ran the CFA on each. We combined factor loadings using Rubin's rules (see(30, 31)).
7 347 There is little guidance on combining model fit statistics across imputations, so we provide the range
8 348 of root mean square error of approximation (RMSEA), comparative fit index (CFI) and Tucker-Lewis
9 349 index (TLI).(32) We considered $RMSEA \leq 0.05$ as indicative of close fit, with $RMSEA \leq 0.08$ as fair fit,
10 350 and CFI and TFI ≥ 0.95 as indicative of acceptable model fit.(22) Final CFA structure was compared to
11 351 bi-factor and hierarchical models using model fit statistics, item loadings and theoretical plausibility.
12
13 352 Measurement invariance was assessed by comparing the final CFA model between girls' who
14 353 reported using only disposable sanitary pads at home, to others. We tested for threshold and
15 354 loading invariance, using updated guidance for multi-group CFA for ordinal data.(33, 34)
16
17 355 Internal consistency was computed using the polychoric, rather than Pearson, correlation matrix to
18 356 generate an ordinal alpha.(35) We also provided Cronbach's alpha based on Pearson's correlations
19 357 for comparison, although this has been suggested to underestimate associations in ordinal data.(35)
20 358 We prioritised capturing experiences across the breadth of menstrual practices, recognising that
21 359 measurement can bias attention towards particular practices. We also hypothesised that girls were
22 360 likely to experience varied practices and environments with different levels of acceptability. Thus, a-
23 361 priori, we were willing to sacrifice some degree of internal consistency for coverage. Nevertheless,
24 362 we applied a conventional $\alpha_{ordinal} \geq 0.70$ as indicative of satisfactory reliability. Test-retest reliability
25 363 was assessed using intra class correlation coefficients (ICCs) calculated using single-measure, two-
26 364 way mixed-effects models, with absolute agreement.(36) We assessed test-retest reliability
27 365 separately for girls reporting on the same or different menstrual period to their original survey.
28 366 Although guidelines on acceptable ICCs are unclear, we considered an ICC between 0.50 and 0.75 to
29 367 represent moderate reliability, and greater than 0.75 to represent good reliability.(36)
30
31 368 The lack of available measures for menstrual health constructs limited comparators for convergent
32 369 or divergent validity. Drawing on hypotheses from qualitative research, we tested construct validity
33 370 though hypothesised associations between the MPNS and confidence to manage menstruation,
34 371 mental health and school absenteeism. Bivariate relationships were tested using Pearson's
35 372 correlation coefficients for continuous variables, and binary logistic regressions for dichotomous
36 373 outcomes (school absenteeism, and confidence to manage menstruation).
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38 374

375 RESULTS

376 Participants

377 A total of 538 menstruating girls were surveyed. The mean age of the sample was 14.49 (SD=1.20).
378 Self-reported ages were 12-19, with one girl indicating 11 years on the survey but reporting being 12
379 during eligibility screening (data retained as part of the sample). Most of the sample were drawn
380 from Primary Class Level (P)6, 59.29%, with an additional 18.40% from P5, 16.91% from P7 and
381 5.39% from P4. Most girls, 72.95%, had repeated a class level. Ninety-five per cent of the population
382 were Christians with the remaining 5% Muslim. Of the sample, 83.07% had gone without food,
383 water, medicine or school supplies in the past year. The mean score for symptoms using DASS-21
384 items was 12.66 (SD=6.48), with possible scores ranging from 0 to 42, with higher scores
385 representing greater generalised negative emotional state.

386 In multi-response option questions capturing all menstrual materials used at home during the last
387 menstrual period: 58.10% of girls used disposable pads, 32.03% reusable pads, 19.93% cloth, 13.22%
388 used their underwear alone, 7.64% toilet paper, 7.26% cotton wool and 5.40% used mattress and
389 other materials. A total of 291 girls (54.49%) washed and reused menstrual materials during their
390 last period.

391 A total of 59.14% changed materials three or more times on their heaviest day. Materials were
392 changed in a bedroom (52.42%), a bathroom (26.39%), latrine (19.89%) or outside (1.30%) when at
393 home. Most girls, 87.71%, had changed materials away from home at least one day during their last
394 period.

395 **Item responses**

396 The proportions of responses, and number of missing, for each item in the 54-item pool are
397 presented in Table 1. Frequencies highlight the menstrual management challenges facing girls. They
398 also show a lower proportion of girls using the 'often' response option. There was a low proportion
399 of missing data across scale items, varying from 0.00%-4.46%. Item mean, standard deviation, skew
400 and kurtosis are presented in Supplementary Materials 1.

401 **Item reduction**

402 We removed items fitting poorly with a parsimonious and theoretically plausible factor structure,
403 and with the objective of balancing length with coverage. This meant poorly loading items, and some
404 items that duplicated concepts and had high intercorrelations were removed. Excluded items, with
405 reasons, are presented in Supplementary Materials 2.

406 Notably for item reduction, only 27% of girls always felt comfortable to use the same location for
407 urination during their period as when they were not menstruating, with a lower 23% of girls
408 comfortable at school (items 33 and 37). This casts some doubts regarding responses to the
409 subsequent items, item 34 and 38, wherein girls reported their worries that others would see their
410 menstrual blood after urination. It is unclear if this question can apply accurately to those who may
411 have avoided usual latrines during menstruation. In EFAs we found items 33 and 37, and items 34
412 and 38 loaded on their own factors. Two-item factors were not considered acceptable for the
413 measure and all four items were excluded.(37)

414

415 **Table 1. Full 54 item pool and participant responding (n=538)**

No.	Item	Never %	Some-times %	Often %	Always %	Missing % (n) ¹
1	I was able to choose the menstrual materials I most wanted to use	14.95	39.44	6.92	38.69	0.56 (3)
2	My menstrual materials were comfortable	14.53	29.62	11.32	44.53	1.49 (8)
3	(r) I worried that my menstrual materials would allow blood to pass through to my outer garments	28.63	38.42	14.69	18.27	1.30 (7)
4	(r) I worried that my menstrual materials would move from place while I was wearing them	30.92	44.08	9.92	15.08	2.60 (14)
5	(r) I worried about how I would get more of my menstrual material if I ran out	23.56	43.87	13.41	19.16	2.97 (16)
6	I had enough of my menstrual materials to change them as often as I wanted to	18.73	33.59	11.58	36.10	3.72 (20)
7	I was satisfied with the cleanliness of my menstrual materials	13.42	23.15	13.04	50.39	4.46 (24)
8	I could get more of my menstrual materials when I needed to	19.35	41.18	13.09	26.38	2.04 (11)
9	I felt comfortable carrying spare menstrual materials with me outside my home	30.86	32.76	10.86	25.52	2.42 (13)
10	I felt comfortable carrying menstrual materials to the place where I changed them	30.12	30.69	11.39	27.80	3.72 (20)
11	I felt comfortable transporting used materials to wash or dispose of them	22.81	31.18	12.74	33.27	2.23 (12)
12	I had a clean place to store my menstrual materials when I was not using them during my period	12.69	23.11	10.42	53.79	1.86 (10)
13	(r) I was worried that someone would see my stored menstrual materials when I was not using them	24.95	44.47	10.32	20.26	0.93 (5)
14	I felt comfortable storing my menstrual materials until my next period	14.66	21.80	7.52	56.02	1.12 (6)
15	I was able to wash my hands <u>when</u> I wanted to	4.31	24.72	6.37	64.61	0.74 (4)
16	I was able to wash my vagina <u>when</u> I wanted to	10.53	16.35	10.71	62.41	1.12 (6)
17	I was able to wash my hands and vagina <u>as often</u> as I wanted to	9.33	20.19	12.00	58.48	2.42 (13)
18	(r) I was concerned that I would not have enough soap to wash my hands or vagina	19.77	46.90	12.98	20.35	4.09 (22)
19	I felt clean during my last period	13.02	25.09	13.09	47.92	1.49 (8)
20	(r) I worried about where to dispose of my used menstrual materials	36.55	30.49	11.93	21.02	1.86 (10)
21	(r) I worried that people, or animals, may be able to access my used menstrual materials after I disposed of them	44.03	30.22	9.89	15.86	0.37 (2)
22	(r) I was concerned that others would see my used menstrual materials in the place I disposed of them	33.02	38.81	12.31	15.86	0.37 (2)
23	I was able to immediately dispose of my used menstrual materials	15.46	26.07	11.73	46.74	0.19 (1)
24	I was able to dispose of my used materials in the way that I wanted to	21.00	19.89	11.90	47.21	0 (0)
25	When at home, I was able to change my menstrual materials <u>when</u> I wanted to	6.16	23.13	6.16	64.55	0.37 (2)
26	When at home, I was satisfied with the place I used to change my menstrual materials	8.07	23.45	12.38	56.10	0.93 (5)
27	When at home, I had a clean place to change my menstrual materials	5.69	18.41	11.76	64.14	2.04 (11)
28	(r) When at home, I worried that I would not be able to change my menstrual materials when I needed to	30.22	35.63	14.93	19.22	0.37 (2)
29	(r) When at home, I worried that someone would see me while I was changing my menstrual materials	30.58	41.65	8.82	18.95	0.93 (5)
30	(r) When at home, I worried that someone would harm me while I was changing my menstrual materials	46.60	26.76	9.81	16.79	1.49 (8)

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31	(r) When at home, I worried that something else would harm me while I was changing my menstrual materials (e.g., animals, insects, unsafe structure)	47.96	32.34	8.36	11.34	0 (0)
32	(r) When at home, I worried that someone would see me when I was washing my vagina	39.25	35.85	8.49	16.42	1.49 (8)
33	When at home, I felt comfortable using the same location for urination as when I do not have my period	37.27	25.84	9.93	26.97	0.74 (4)
34	(r) When at home, I worried that others would see my menstrual blood after I had urinated	29.66	38.43	9.70	22.20	0.37 (2)
35	When at school, I was able to change my menstrual materials when I wanted to	34.51	33.77	6.72	25.00	0.37 (2)
36	When at school, I was satisfied with the place I used to change my menstrual materials	29.06	30.19	12.08	28.68	1.49 (8)
37	When at school, I felt comfortable using the same location for urination as when I do not have my period	38.97	28.25	9.60	23.35	1.30 (7)
38	(r) When at school, I worried that others would see my menstrual blood after I had urinated	28.89	39.77	10.69	20.64	0.93 (5)
39	When at school, I had a clean place to change my menstrual materials	30.17	26.94	10.44	32.45	2.04 (11)
40	(r) When at school, I worried that I would not be able to change my menstrual materials when I needed to	23.21	41.51	13.02	22.26	1.49 (8)
41	(r) When at school, I worried that someone would see me while I was changing my menstrual materials	28.63	39.55	12.99	18.83	1.30 (7)
42	(r) When at school, I worried that someone would harm me while I was changing my menstrual materials	37.83	30.90	10.67	20.60	0.74 (4)
Items relevant to those washing and reusing materials (n=291)						
43	I had enough water to soak or wash my menstrual material	6.23	20.76	5.54	67.47	0.69 (2)
44	I had access to a basin to soak or wash my menstrual materials whenever I needed it	13.06	26.12	9.97	50.86	0 (0)
45	I was able to wash my menstrual materials when I wanted to	15.14	23.94	7.75	53.17	2.41 (7)
46	I had enough soap to wash my menstrual materials	8.80	31.34	9.51	50.35	2.41 (7)
47	(r) I worried that someone would see me while I was washing my menstrual materials	27.92	42.76	12.01	17.31	2.75 (8)
48	(r) I worried about how I would get soap to wash my menstrual materials	31.07	38.93	12.14	17.86	3.78 (11)
49	(r) I worried that my menstrual materials would not be dry when I needed them	31.49	39.10	13.49	15.92	0.69 (2)
50	(r) I worried that others would see my menstrual materials while they were drying	23.08	42.31	12.24	22.38	1.72 (5)
51	I was able to dry my materials when I wanted to	12.98	22.11	13.33	51.58	2.06 (6)
52	I was satisfied with the place I used to dry my menstrual materials	15.03	25.87	9.44	49.65	1.72 (5)
53	I was satisfied with the appearance of my menstrual materials after I had cleaned them	8.04	24.83	12.24	54.90	1.72 (5)
54	I was satisfied with the smell of my menstrual materials after I had cleaned them	21.80	25.26	7.27	45.67	0.69 (2)

416 (r) reverse scored. ¹ excluded from calculation of response percentages

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419 Dimensionality

420 EFA on the first random split-half of the data was undertaken, first for the items applying to all
421 respondents (n=261). This process concluded with a 28-item, four-factor solution explaining 80% of
422 the total variance. Factorability was confirmed through visual inspection of the polychoric
423 correlation matrix, and Kaiser-Meyer-Olkin (KMO) sampling adequacy of 0.72 for the final 28-item
424 split-half sample. Thirteen girls were missing more than two items on the final 28 core items that
425 applied to all respondents. These participants were excluded from subsequent analyses.

426 A separate EFA was undertaken in the sub-sample of participants who reported they had washed
427 and reused materials during their last period and answered questions concerning washing and
428 drying during the last period (n=286). A two-factor solution was retained, with a total of eight items
429 of the original 12. Factor structure and loadings are presented in Table 2.

430 EFA was followed by a CFA of the second split-half of the data for the 28 core items (n=264), and the
431 entire subset of those reusing materials for the additional 8 reuse items. As noted in methods, we
432 undertook multiple imputation to generate 10 imputed data sets and combined factor loading
433 estimates using Rubin's rules.⁽³⁰⁾ We provide the range of fit statistics from the CFAs undertaken on
434 each imputation. The four-factor model was a good fit for the data (RMSEA=0.028-0.029; CFI=0.961-
435 0.964; TFI=0.957-0.959). In the initial EFA solution two items (9 and 10) were cross loaded on home
436 and school-related domains. This fit theoretically with the data since these items did not specify a
437 location. In CFA on the second split-half, these items loaded more strongly on the school-factor and
438 loaded poorly on the home-factor. These items were retained under only the 'transport and school
439 environment needs' factor. A final CFA on the full data set (including all participants) supported good
440 model fit for the core 28-items (RMSEA=0.028-0.029; CFI=0.957-0.959; TFI=0.953-0.955), and the
441 additional reuse items (RMSEA=0.021-0.030; CFI=0.987-0.994; TFI=0.981-0.991), pooled across the
442 10 imputations.

443 The CFA on the full data set was compared to bi-factor and hierarchical models using structural
444 equation models (SEM). Neither a bi-factor (RMSEA=0.041; CFI=0.913; TFI=0.906) nor a hierarchical
445 model (RMSEA=0.051; CFI=0.877; TFI=0.855) were a better fit for the first imputed data set and were
446 not investigated further.

447 Model invariance in the full data set was assessed, comparing those exclusively using disposable
448 sanitary pad (n=191) to others (n=334). A model constraining both thresholds and loadings remained
449 an acceptable fit (RMSEA=0.029; CFI=0.948; TFI=0.947) supporting the generalisation of latent
450 constructs (subscales) across these two groups and suggesting that scores can be meaningfully
451 compared across those using different menstrual materials. Item 6, having enough materials to
452 change as often as desired, loaded more poorly when groups were separated (estimate=0.36) which
453 may indicate some variability in this question based on material type.

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456 Table 2. Factor structure and loadings for split-half EFA, CFA, and full sample CFA

Item	Split-half EFA (n=261)	Split-half CFA (n=264)	Full sample Final CFA (n=525)
Material and home environment needs			
2 My menstrual materials were comfortable	0.46	0.62	0.53
6 I had enough of my menstrual materials to change them as often as I wanted to	0.45	0.52	0.45
7 I was satisfied with the cleanliness of my menstrual materials	0.62	0.58	0.62
8 I could get more of my menstrual materials when I needed to	0.38	0.54	0.49
9 I felt comfortable carrying spare menstrual materials with me outside my home	0.36	-0.03	-
10 I felt comfortable carrying menstrual materials to the place where I changed them	0.36	0.11	-
14 I felt comfortable storing my menstrual materials until my next period	0.71	0.41	0.53
15 I was able to wash my hands when I wanted to	0.64	0.64	0.59
23 I was able to immediately dispose of my used menstrual materials	0.52	0.54	0.58
24 I was able to dispose of my used materials in the way that I wanted to	0.43	0.61	0.56
25 When at home, I was able to change my menstrual materials when I wanted to	0.75	0.62	0.67
26 When at home, I was satisfied with the place I used to change my menstrual materials	0.61	0.68	0.67
27 When at home, I had a clean place to change my menstrual materials	0.71	0.60	0.65
Transport and school environment needs			
9 I felt comfortable carrying spare menstrual materials with me outside my home	0.27	0.63	0.58
10 I felt comfortable carrying menstrual materials to the place where I changed them	0.25	0.47	0.58
35 When at school, I was able to change my menstrual materials when I wanted to	0.55	0.60	0.60
36 When at school, I was satisfied with the place I used to change my menstrual materials	0.65	0.63	0.62
39 When at school, I had a clean place to change my menstrual materials	0.76	0.66	0.64
Material reliability concerns			
3 I worried that my menstrual materials would allow blood to pass through to my outer garments	0.63	0.51	0.53
4 I worried that my menstrual materials would move from place while I was wearing them	0.31	0.51	0.54
5 I worried about how I would get more of my menstrual material if I ran out	0.57	0.55	0.52
Change and disposal insecurity			
20 I worried about where to dispose of my used menstrual materials	0.40	0.49	0.48
22 I was concerned that others would see my used menstrual materials in the place I disposed of them	0.49	0.61	0.57
28 When at home, I worried that I would not be able to change my menstrual materials when I needed to	0.47	0.50	0.50
29 When at home, I worried that someone would see me while I was changing my menstrual materials	0.31	0.54	0.52
30 When at home, I worried that someone would harm me while I was changing my menstrual materials	0.72	0.78	0.72
31 When at home, I worried that something else would harm me while I was changing my menstrual materials (e.g., animals, insects, unsafe structure)	0.50	0.66	0.64
40 When at school, I worried that I would not be able to change my menstrual materials when I needed to	0.62	0.46	0.48
41 When at school, I worried that someone would see me while I was changing my menstrual materials	0.54	0.51	0.53
42 When at school, I worried that someone would harm me while I was changing my menstrual materials	0.54	0.66	0.57

Reuse items	Full-sample EFA (n=286)	(N/A)	Full sample CFA (n=286)
Reuse needs			
43 I had enough water to soak or wash my menstrual material	0.71	-	0.74
44 I had access to a basin to soak or wash my menstrual materials whenever I needed it	0.53	-	0.53
45 I was able to wash my menstrual materials <u>when</u> I wanted to	0.58	-	0.59
46 I had enough soap to wash my menstrual materials	0.66	-	0.68
51 I was able to dry my materials <u>when</u> I wanted to	0.57	-	0.58
Reuse insecurity			
47 I worried that someone would see me while I was washing my menstrual materials	0.57	-	0.69
49 I worried that my menstrual materials would not be dry when I needed them	0.42	-	0.45
50 I worried that others would see my menstrual materials while they were drying	0.54	-	0.53

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459 **Scale scores and reliability**

460 Subscale scores and total score were calculated as mean scores where never=0, sometimes=1,
461 often=2 and always=3 for positively coded items, and the reverse for negatively coded items. All
462 subscales have ranges from 0 to 3, and higher scores represent more positive experiences. Subscales
463 specific to those reusing materials were only calculated for this population. Total score included
464 reuse items for those to whom these were applicable. The distributions of scale scores are displayed
465 for the total scale and sub-scales in Supplementary Materials 1. Plots showing relationships between
466 the core four factors, and the total score are displayed in Supplementary Materials 3.

467 Cronbach's α , and ordinal α are presented in Table 3. Acceptable reliability was achieved for most
468 subscales. The two three-item subscales, material concerns and reuse insecurity, had poorer internal
469 consistency.

470 Fifty-six girls completed the re-test survey. Of those, three were missing scores on MPNS items at
471 original survey, and one had more than two missing items on the retest. Test-retest reliability for the
472 52 participants with repeat data using single-measure ICC are displayed in Table 3. Reliability varied
473 meaningfully between girls we estimated to be reporting on the same menstrual period as the
474 original survey, compared to those who reported having a new period. We took the reliability among
475 the subsample of girls reporting on the same menstrual period (n=20) as indicative of scale reliability
476 as questions specifically ask about the last period.

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479 **Table 3. Scale scores, internal consistency, test-retest reliability, and interrelationships**

	Mean (SD)	Skew, Kurtosis	Internal Consistency		Test-retest reliability ICC _(2,1) (95%CI)		Correlations between subscales (Pearson's r)					
			α	Ordinal α	Same period (n=20)	New period (n=32)	1	3	4	5	6	
Total score (n=525)	1.82 (0.37)	0.20, 3.17	0.77	0.82	0.69 (0.36-0.86)	0.30 (-0.05-0.58)	0.75	0.54	0.31	0.44	0.51	0.30
1. Material and home environment needs	1.99 (0.62)	-0.35, 2.40	0.79	0.84	0.53 (0.12-0.78)	0.46 (0.14-0.69)	1.00	0.51	-0.08	-0.15	0.65	-0.02
2. Transport and school environment needs	1.35 (0.78)	0.20, 2.21	0.66	0.73	0.67 (0.33-0.85)	0.22 (-0.14-0.53)	-	0.00	-0.20	-0.24	0.43	-0.09
3. Material reliability concerns	1.81 (0.73)	-0.48, 2.64	0.51	0.55	0.24 (-0.22-0.61)	0.08 (-0.27-0.41)	-	0.00	1.00	0.43	-0.01	0.35
4. Change and disposal insecurity	1.87 (0.61)	-0.50, 3.29	0.74	0.80	0.56 (0.17-0.80)	0.16 (-0.20-0.48)	-	0.00	-	1.00	-0.15	0.50
5. Reuse needs (n=286)	2.08 (0.72)	-0.64, 2.74	0.66	0.76	n=12 0.67 (0.19-0.89)	n=17 0.72 (0.38-0.89)	-	0.00	-	-	1.00	0.06
6. Reuse insecurity (n=286)	1.78 (0.73)	-0.20, 2.38	0.47	0.56	-0.07 (-0.60-0.50)	0.23 (-0.26-0.63)	-	0.00	-	-	-	1.00

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483 Validity

484 Content validity of the scale was assessed through comparison with findings from qualitative
485 research, FGDs with enumerators undertaking surveys of menstrual hygiene, feedback from research
486 assistants in Soroti, Uganda, input from NGO monitoring and evaluation officers and online survey of
487 experts.

488 For construct validity, we tested associations between scale scores and confidence to manage
489 menstruation, school absenteeism, and mental health symptoms. Bivariate associations are
490 presented in Table 4. Fewer worries about material reliability and changing were associated with
491 fewer depression and anxiety symptoms. In contrast, positive perceptions of material, home and
492 school environment needs were weakly associated with mental health.

493 More positive perceptions of materials, home and school environments were associated with
494 significantly higher odds of feeling confident to manage menstruation at home or school. Supporting
495 item validity, positive school assessment was not associated with confidence at home. Material and
496 home environments did show a weaker, but positive relationship with school management
497 confidence, however this subscale includes items regarding menstrual materials and disposal which
498 are likely to cross settings. Fewer concerns about material reliability, insecurity in changing and
499 disposal access across contexts, and more positive perceptions of materials and home environments
500 were associated with higher odds of attending school during menstruation. A higher MPNS total
501 score, which captures girls' perceptions across all practices and environments, was associated with
502 much higher odds of confidence to manage menstruation and attending school during menses.

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504 **Table 4. Bivariate associations between scale scores and hypothesised correlates**

		Material and home environment	Transport and school environment	Material reliability concerns	Change and disposal insecurity	Total
		<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)	<i>r</i> (<i>p</i>)
DASS-21 total score ¹ (n=518)		0.04 (<i>p</i> =.333)	0.16 (<i>p</i> <.001)	-0.27 (<i>p</i> <.001)	-0.26 (<i>p</i> <.001)	-0.11 (<i>p</i> =.013)
	%	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Felt confident to manage menstruation at home ²	80.92	2.87 (1.99,4.15)	1.25 (0.94,1.67)	1.09 (0.81,1.47)	0.92 (0.64,1.31)	4.09 (2.14,7.81)
Felt confident to manage menstruation at school	51.72	1.97 (1.47,2.63)	1.94 (1.53,2.45)	1.14 (0.90,1.44)	1.05 (0.80,1.39)	4.22 (2.52,7.06)
Does not usually miss school during menstruation	61.90	1.48 (1.11, 1.97)	1.14 (0.91,1.43)	1.28 (1.00,1.63)	1.33 (1.00,1.77)	2.52 (1.52,4.17)
Did not miss school during last menstrual period	69.25	1.11 (0.82,1.50)	0.99 (0.78,1.26)	1.54 (1.19,2.00)	2.10 (1.51,2.91)	2.62 (1.52,4.50)

505 ¹ DASS score ranges from 0-42, higher scores indicate greater negative emotional state (combined anxiety and
506 depression items). DASS scores exhibited acceptable normality for parametric testing (see Supplementary
507 Materials 1). ² not confident = 1.00

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3 509**DISCUSSION**

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5 510 The Menstrual Practice Needs Scale (MPNS-36) is a self-report measure to evaluate the extent to
6 511 which an individuals' menstrual management practices and environments are perceived to meet
7 512 their needs. Development was informed by past research, including review of qualitative and
8 513 quantitative studies, and expert input.(3, 16, 17, 38) The final tool reflects experiences across a
9 514 range of practices. Emergent factors were theoretically plausible and translated into interpretable
10 515 subscales. The MPNS demonstrated good internal consistency, and acceptable test-retest reliability.
11 516 Associations with hypothesised correlates supported the validity of the measure and its use in future
12 517 research.

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15 518 We hypothesised a-priori that emergent factors would reflect groups of practices, and that
16 519 appraisals of environments would load on separate factors. Hypotheses were partially supported.
17 520 The final four-and two-factor structure separated girls' appraisals of the reliability of their menstrual
18 521 materials, home, and school environments. However, items capturing worries and concerns about
19 522 changing environments, disposal and materials, loaded separately from ratings of comfort,
20 523 satisfaction and adequacy of practices. These factors were not strongly correlated, or in the case of
21 524 'transport and school environment needs' and 'change and disposal insecurity', showed a small to
22 525 modest negative correlation. Taken together, relationships suggest that greater satisfaction and
23 526 comfort with menstrual practices does not translate into fewer worries about their reliability or risks
24 527 to privacy or safety. Appraisals of privacy needs may be more strongly dictated to by internalised
25 528 menstrual stigma, social relationships and norms, independent of the acceptability and comfort of
26 529 other practices. Inspection of bivariate correlations suggested that trade-offs may be made between
27 530 the favourability of the location to change menstrual materials and the accessibility of disposal
28 531 options, contributing to negative subscale correlations. The use of 'worries' terminology in scale
29 532 items was selected to best align with past qualitative reports and to prevent confusion which may
30 533 arise in positively and negatively worded items using the same response options.(3, 39) However, we
31 534 acknowledge this may have been more likely to evoke anxieties than items asking about 'comfort' or
32 535 having 'enough' of various resources. Feedback from enumerators suggested that girls in this study
33 536 did not struggle with the nature of these items as the response options were in the affirmative
34 537 direction for all questions. Enumerators did report that a measure included for validation, the
35 538 Rosenberg Self-Esteem Scale,(40) which included positively and negatively worded items through
36 539 use of alternate wording like "I do" versus "I do not" with the same response options caused
37 540 difficulties for respondents. There was no such evidence of difficulties with reverse coded items in
38 541 the MPNS-36 in enumerator feedback, frequencies, or visual inspection of surveys. Future research
39 542 is needed to further investigate the interrelationships between menstrual needs, insecurities, and
40 543 how females make menstrual practice decisions.

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43 544 Measuring women's and girls' menstrual practice needs involves gaining an understanding of the
44 545 acceptability, comfort, reliability of practices and insecurities around privacy, safety and exposure of
45 546 menstrual status. Drawing on this theoretical underpinning, and the relatively acceptable
46 547 performance of bi-factor and hierarchical models including a total score, we would argue that a total
47 548 score capturing perceptions across the range of practice and environmental needs is appropriate.
48 549 This score is likely to be of use to researchers and practitioners, summarising experience across the
49 550 breadth of behaviours. Subscale and total scores were calculated using mean scores rather than
50 551 factor scores. Mean scores allow for correction of single missing data points, by averaging across
51 552 other items, and are accessible for practitioners who may not have access to the statistical packages
52 553 needed to calculate factor scores. Since much of the data on menstrual experiences is collected as

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3 554 part of NGO monitoring and evaluation, comparability across these data and that in research studies
4 555 is valuable so we suggest researchers use mean scores.

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6 556 Insecurities about the privacy and safety of the locations used to change menstrual materials loaded
7 557 on the same factor for questions concerning home and school environments. It is important to note
8 558 that this indicates that these ratings co-varied, not that change locations in these settings were given
9 559 the same ratings. School environments received much more negative appraisals, captured through
10 560 frequencies and means. For research or practice evaluation that focuses on either home or school
11 561 environments, the separate appraisal of location-specific subscales may need to be validated.
12 562 However, further investigation is needed as covariation of home and school privacy ratings could
13 563 suggest interdependencies between the two. It is plausible that experiences and learned
14 564 expectations from home environments influence perceptions of school environments. Changes to
15 565 individuals' expectations for their menstrual experience in response to interventions was an
16 566 overarching theme of a recent meta-synthesis of qualitative studies of menstrual health
17 567 interventions and would fit with this interpretation of our findings.(41) Alternatively, a joint
18 568 predictor, such as internalised stigma, may contribute to both appraisals. This should be explored in
19 569 future research and may indicate the need to assess both location responses even if interventions
20 570 only focus on school infrastructure.

21 571 **Strengths and limitations**

22 572 Development of items drawing on the experiences of women and girls across low- and middle-
23 573 income countries through systematic review indicates the potential for the MPNS-36 to be relevant
24 574 across contexts and populations. This approach was undertaken at the cost of specificity for the pilot
25 575 population. A measure developed through qualitative study of the Soroti schoolgirl population may
26 576 have yielded a different prioritisation of items. However, we were mindful of the ongoing
27 577 measurement needs across contexts and calls for improved comparability, particularly across trial
28 578 studies.(5, 8) At the same time, piloting and validation was undertaken in a single population
29 579 (menstruating schoolgirls in Soroti) and the measure should be evaluated in other languages,
30 580 settings, and groups (e.g., adult women, out-of-school girls). Feedback from FGDs with enumerators
31 581 in Niger, and online survey of experts suggest some languages or contexts may favour a 3-point
32 582 response scale. Adapted response options as "less than half the time" and "more than half the time"
33 583 may be more specific replacements for "sometimes" and "often" depending on the language of the
34 584 scale. Our validation was limited by the lack of past quantitative research on quantitative
35 585 relationships between menstrual experience and outcomes, and the absence of other measures
36 586 against which to assess convergent or divergent validity. Hypothesised relationships were tested
37 587 cross-sectionally and we cannot draw directional or causal inferences from these findings. Our
38 588 group-survey approach reduced costs and allowed girls to self-mark their responses rather than
39 589 declaring them directly to an enumerator, however this may have introduced error in marking the
40 590 intended response or due to the group setting.

41 591 Some items asked of all respondents may not be applicable. For example, those who avoid school
42 592 during menstruation were still asked about cleanliness, privacy and safety concerns and may report
43 593 fewer worries as they manage their needs by avoiding changing materials at school. For simplicity,
44 594 we recommend not using additional filters to questions, however response patterns should be
45 595 explored in future studies and through cognitive interviewing, particularly where the measure is
46 596 used in intervention studies. We received feedback on item interpretability from research assistants
47 597 fluent in Ateso and local to the Soroti area, however we were unable to undertake cognitive
48 598 interviews with schoolgirls which could have improved the development process. Future studies
49 599 should address this gap and may identify improvements to items.

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3 600 As noted in methods, item reduction drew on factor analysis, but also considered the need for
4 601 content validity through the coverage of different menstrual practices. We also prioritised brevity.
5 602 Decisions to remove some items, such as those that were felt to duplicate practices may have
6 603 reduced the internal consistency metrics of the scale but ensured items represented the breadth of
7 604 practice experiences. Two subscales of three items each, 'material reliability concerns' and 'reuse
8 605 insecurity' did not achieve acceptable internal consistency or test-retest reliability. This is likely due
9 606 to the small number of items and variability within the short set. We retained these as separate
10 607 subscales as we recognise concerns about the performance of menstrual materials and worries
11 608 about exposure during washing and drying are salient parts of menstrual experiences.(3, 12)
12 609 Additional or refined items tested in future studies may improve the reliability of these subscales.

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16 610 Test-retest reliability was assessed in a small sub-sample of participants. This sample size was
17 611 reduced further due to the differential reliability between those reporting on the same menstrual
18 612 period as their original survey. These data raise questions regarding the variability of menstrual
19 613 experiences. Findings could also suggest that participating in the survey made girls more attentive to
20 614 their needs during subsequent periods, leading to a change in their appraisals, a possibility that
21 615 should be explored in subsequent studies and larger samples.

22 23 24 616 **Implications for research and practice**

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26 617 Quantitative study of menstrual experiences has focused on measures of menstrual practices.
27 618 Practices warrant investigation, however, increasingly menstrual health programming and policy
28 619 have recognised that individuals and communities vary in their preferences and the practices viewed
29 620 as preferable or acceptable.(42) The MPNS-36 prioritises participant perceptions of adequacy above
30 621 researcher-defined 'adequate' menstrual practices. Although the definition of menstrual hygiene has
31 622 evolved, the measure also provides an assessment of self-perceived menstrual hygiene status.

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34 623 To date, research has relied on single practices, typically use of sanitary pads, to test associations
35 624 between menstrual health and hypothesised consequences on school absenteeism or wellbeing.
36 625 Such analyses fail to incorporate the range of practices needed for menstrual management, and
37 626 poorly translate the findings from qualitative research into quantitative research questions. The
38 627 MPNS-36 offers a way to test relationships between overarching menstrual practice experience and
39 628 education, health, wellbeing and social participation consequences in cross-sectional or longitudinal
40 629 studies. The measure could be applied in needs assessments or NGO monitoring and evaluation. The
41 630 MPNS-36 could be used in trials of menstrual health interventions to assess how programs change
42 631 practice experiences and would likely represent a key mediating assumption between interventions
43 632 such as product provision or sanitation improvements, and end line impacts such as school
44 633 attendance. Future studies will be needed to test the association between practice needs as
45 634 measured through the MPNS-36 and school attendance, triangulating self-report data with more
46 635 reliable methods such as school spot-checks.

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50 636 Although the tested scale specified school as the location for a subset of items, this wording could be
51 637 adapted to the workplace, or when 'away from home' when applied to adult or out-of-school
52 638 samples. These groups require more attention,(3) and investigation of scale performance in these
53 639 populations would be of value.

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56 640 In sum, the menstrual practice needs scale is a self-report measure specifically developed to assess
57 641 the extent to which an individuals' menstrual management practices and environments are
58 642 perceived to meet their needs. The final instrument has high face validity and evidence of content

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3 643 validity, reflecting experiences across a range of practices and the total and subscale scores could be
4 644 useful in needs assessment, monitoring and exploring intervention impact.
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For peer review only

646 **Ethical approvals**

647 All girls provided signed assent to participate. Parents were informed about the study through
648 parent-teacher meetings at each school, teacher contact with parents, and information sheets in
649 English and Ateso sent home with girls prior to the study. Parents were asked to contact the school
650 or study staff if they did not consent to daughters' participation, or express concerns during parent-
651 teacher meetings. No parents expressed concerns about the study and no girls declined
652 participation.

653 Ethical approval was provided by Johns Hopkins School of Public Health Institutional Review Board
654 (IRB approval no: 00009073), and the Mildmay Uganda Research Ethics Committee (MUREC)
655 (approval ref: 0212-2018). The Uganda National Council for Science and Technology (UNCST)
656 approved the study (ref: SS279ES). Feedback on draft measure items by experts through online
657 survey and focus group discussions of resident enumerators in Niger were exempted from ethical
658 review by the Johns Hopkins School of Public Health Institutional Review Board. Participants of these
659 consultations consented to participate.

660 **Patient and Public Involvement**

661 This manuscript reports on the development and validation of a measure of menstrual practice
662 needs. Potential users of the measure, researchers and NGO practitioners, were included in the
663 research process through an expert survey to solicit feedback on the measure. Further, we
664 undertook focus group discussions with data collection staff to engage their feedback. Patients/the
665 public were not involved in the study design. Dissemination of this work was developed with
666 collaboration from the implementing partner NGO, Irise Institute East Africa.

667 **Acknowledgements**

668 We are most grateful to the participating girls and schools, and the dedicated team of research
669 assistants who undertook data collection. We thank Dr Christian van Engers for developing the code
670 for visual representation of the data in Supplementary Materials 3 and the administration of the
671 www.menstrualpracticemeasures.org website. We are grateful to Prof. G.J. Melendez-Torres for his
672 statistical guidance. We are indebted to the numerous experts in menstrual health who took the
673 time to review draft items and provide their insights.

674 **Funding**

675 This study was funded by The Case for Her and the Osprey Foundation of Maryland.

676 **Contributions**

677 JH designed the study, undertook analysis, interpretation, and wrote the first draft of the
678 manuscript. AN, CS, MR, KJS, AA, contributed to study design, interpretation, and critically reviewed
679 the manuscript. MR critically reviewed measure materials and analytic strategy. AN coordinated data
680 collection and implemented study protocols. AA facilitated translation and back-translation of survey
681 tools, supported data collection and feedback on the performance of items. All authors have
682 approved the final manuscript.

683 **Data sharing statement**

684 Deidentified data is available from: <https://osf.io/qshkc/>. The final MPNS-36 measure and scoring
685 information is available online from www.menstrualpracticemeasures.org

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3 687 **Competing interests**
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5 688 Calum Smith works for Irise International, an organisation dedicated to creating a world where all
6 689 women and girls can reach their full potential, regardless of their periods. Irise International receives
7 690 funding from various sources to develop school-based menstrual health interventions in East Africa
8 691 and from Sustain for Life to work with schools in Soroti, Uganda. Agnes Nansubuga and Agnes Akullo
9 692 work for Irise Institute East Africa, a local implementing partner of Irise International.

10 693 JH, MR, KJS declare no competing interests.
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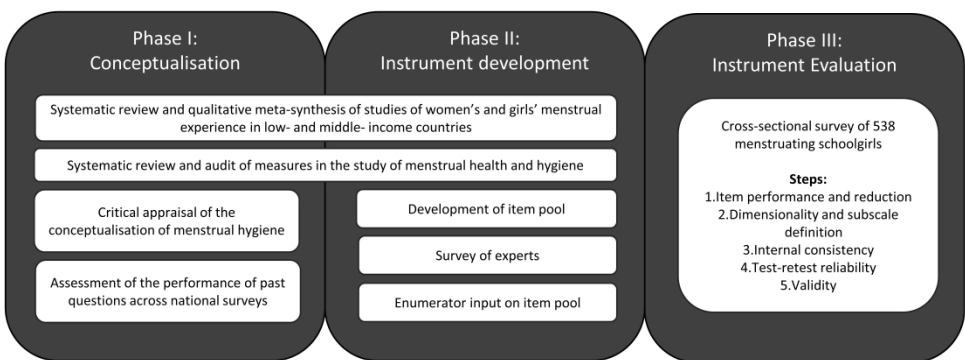


Figure 1. Phases of development of the MPNS-36

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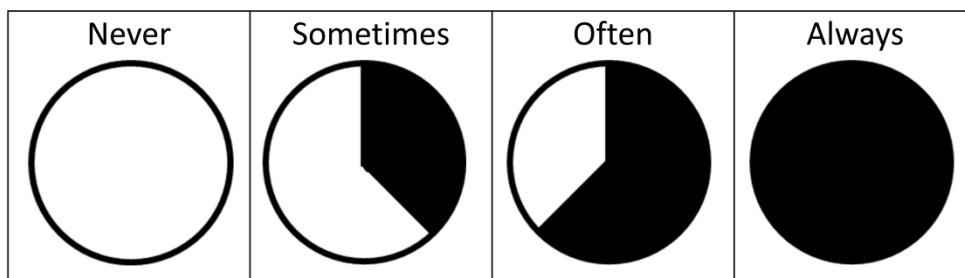


Figure 2. Visual chart for MPNS item response options

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Supplementary Materials 1

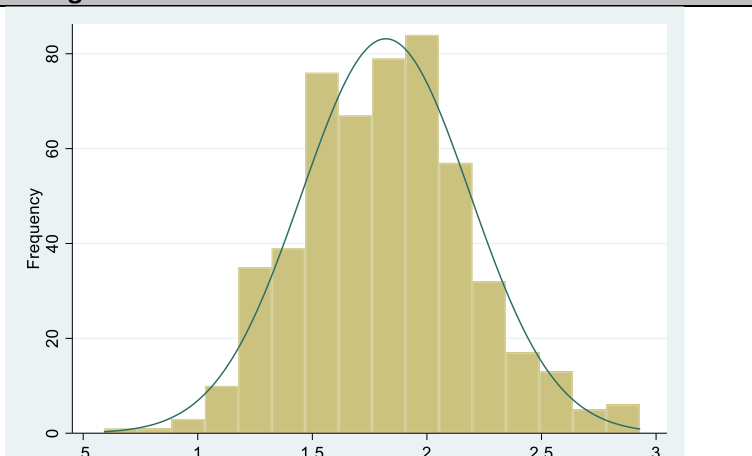
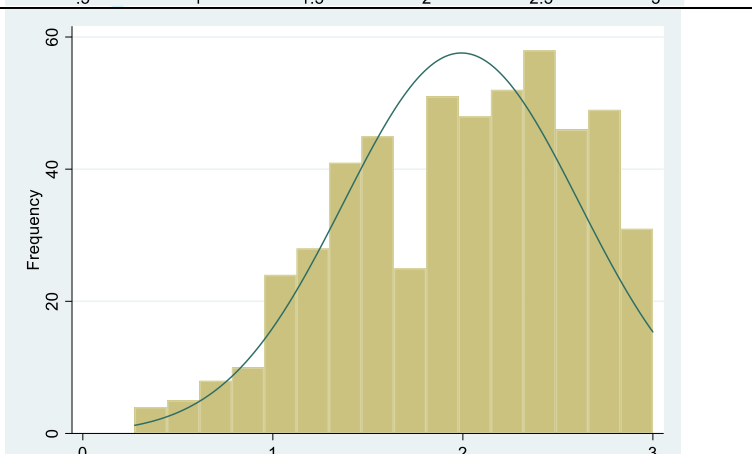
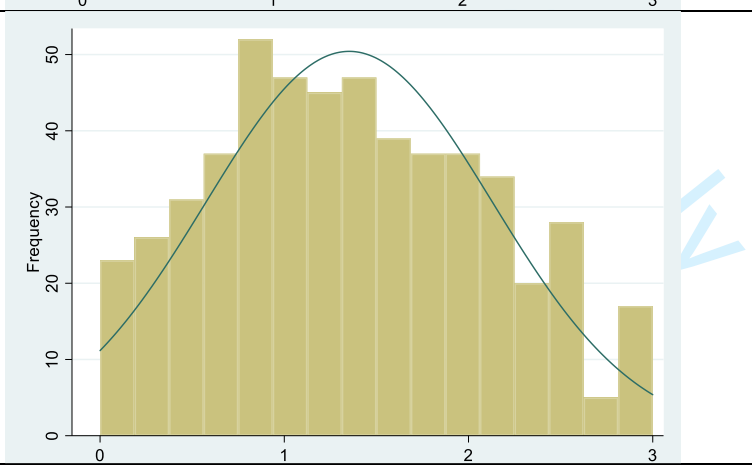
Additional variable descriptive statistics and distributions

Table 1. Mean, standard deviation (SD), skew and kurtosis for each of the 54-items in the full pool

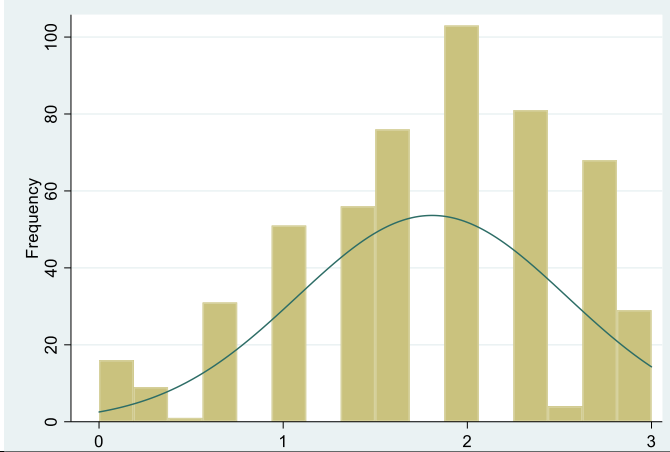
Item number	Mean	SD	Skew	Kurtosis
1	1.69	1.13	0.00	148
2	1.86	1.14	-0.31	1.56
3	1.77	1.06	-0.47	2.03
4	1.91	1.00	-0.72	2.49
5	1.72	1.03	-0.47	2.10
6	1.65	1.15	-0.03	1.51
7	2.00	1.13	-0.57	1.79
8	1.46	1.08	0.26	1.76
9	1.31	1.16	0.36	1.68
10	1.37	1.18	0.27	1.58
11	1.56	1.17	0.04	1.51
12	2.05	1.13	-0.63	1.83
13	1.74	1.05	-0.53	2.10
14	2.05	1.17	-0.65	1.78
15	2.31	0.98	-0.93	2.25
16	2.25	1.07	-1.02	2.51
17	2.20	1.06	-0.87	2.25
18	1.66	1.01	-0.46	2.10
19	1.97	1.12	-0.50	1.74
20	1.83	1.14	-0.80	2.30
21	2.02	1.18	-0.80	2.30
22	1.89	1.04	-0.63	2.25
23	1.90	1.16	-0.40	1.60
24	1.85	1.22	-0.41	1.53
25	2.29	1.02	-0.95	2.32
26	2.17	1.05	-0.76	2.08
27	2.34	0.97	-1.11	2.79
28	1.77	1.08	-0.45	1.93
29	1.84	1.06	-0.63	2.18
30	2.03	1.11	-0.80	2.22
31	2.17	0.99	-1.04	2.97
32	1.98	1.07	-0.77	2.35
33	1.27	1.22	0.38	1.56
34	1.76	1.11	-0.49	1.91
35	1.22	1.17	0.50	1.77
36	1.40	1.18	0.22	1.55
37	1.18	1.18	0.52	1.75
38	1.77	1.08	-0.51	2.00
39	1.45	1.23	0.15	1.43
40	1.66	1.07	-0.39	1.91
41	1.78	1.06	-0.50	2.05
42	1.86	1.14	-0.57	1.90

Items relevant to those washing and reusing materials (n=291)				
Item number	Mean	SD	Skew	Kurtosis
43	2.34	1.01	-1.09	2.60
44	1.99	1.14	-0.51	1.69
45	1.99	1.18	-0.54	1.67
46	2.01	1.08	-0.45	1.65
47	1.81	1.03	-0.58	2.22
48	1.83	1.06	-0.57	2.12
49	1.86	1.03	-0.59	2.21
50	1.66	1.07	-0.41	1.93
51	2.04	1.12	-0.62	1.86
52	1.94	1.17	-0.45	1.61
53	2.14	1.05	-0.70	1.99
54	1.77	1.24	-0.25	1.40

Table 2. Histograms showing the pattern of responses for MPNS-36 total and sub-scale scores

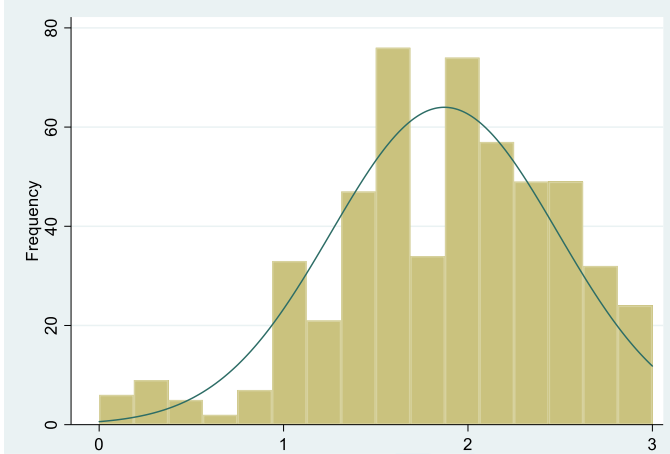
Scale	Histogram	Skew, Kurtosis
Total score (n=525)		0.20, 3.17
1. Material and home environment needs		-0.35, 2.40
2. Transport and school environment needs		0.20, 2.21

3. Material reliability concerns



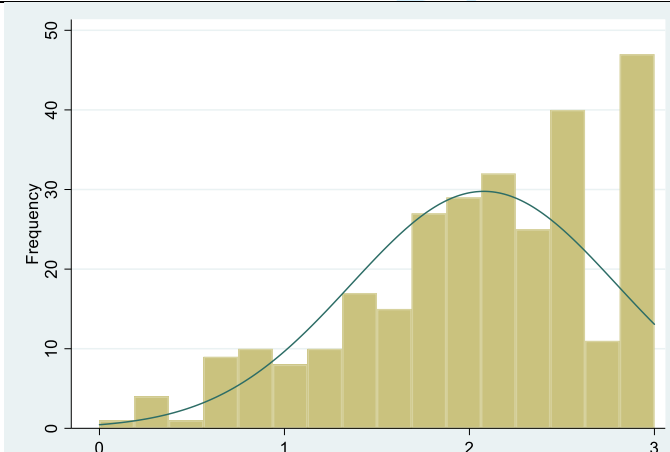
-0.48, 2.64

4. Change and disposal insecurity



-0.50, 3.29

5. Reuse needs (n=286)



-0.64, 2.74

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6. Reuse
insecurity
(n=286)

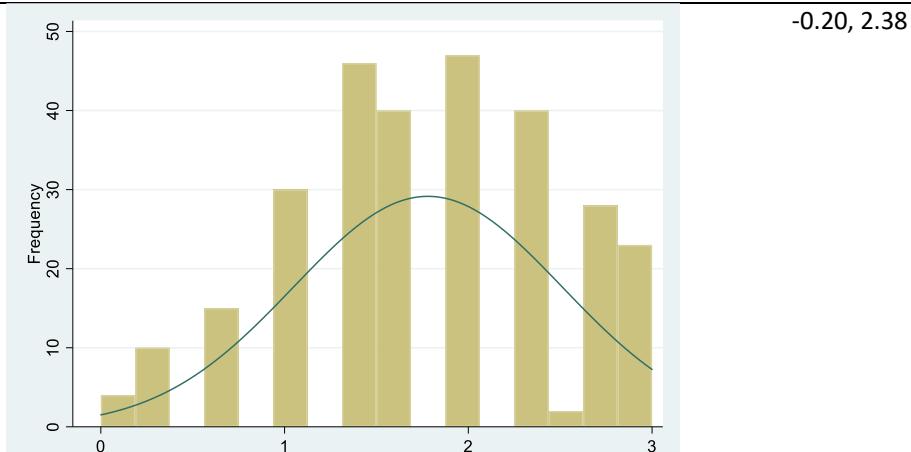
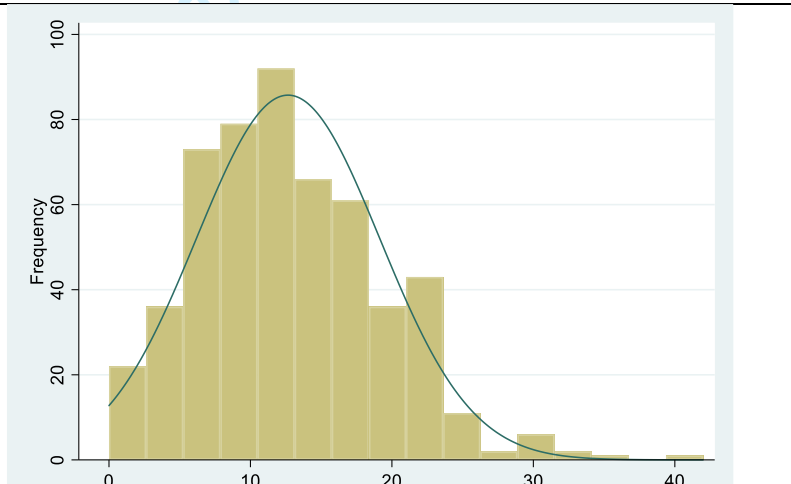


Table 3. Item mean, standard deviation, skew and kurtosis for the DASS-21 total score

Scale	Mean	SD	Skew	Kurtosis
DASS Total Score	12.66	6.49	0.63	3.06



Supplementary Materials 2

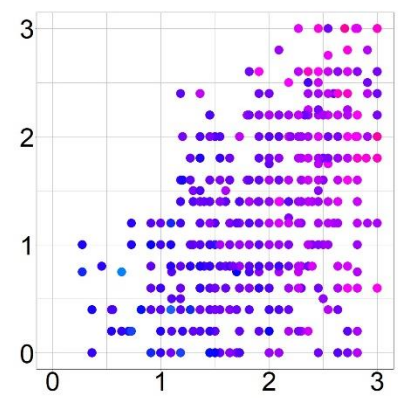
Removed items with reasons for removal

No.	Item	Reasons for removal
1	I was able to choose the menstrual materials I most wanted to use	Removed for scale length and balance of materials-focused items, represented by other items
11	I felt comfortable transporting used materials to wash or dispose of them	Low loading (0.28), better represented by 9 and 10.
12	I had a clean place to store my menstrual materials when I was not using them during my period	Cross-loaded negatively with material reliability concerns (-0.39). Storage captured by item 14.
13	(r) I was worried that someone would see my stored menstrual materials when I was not using them	Poor loading in initial EFA. Some cross-loading with urination items (33, 37). Storage remains captured by item 14.
16	I was able to wash my vagina <u>when</u> I wanted to	Items 15, 16, 17 all loaded highly on material and household facility needs factor and were highly correlated with one another. 16 removed for length and focus on menstrual experience.
17	I was able to wash my hands and vagina <u>as often</u> as I wanted to	Removed as above, and for cross-loading with material reliability concerns (-0.38)
18	(r) I was concerned that I would not have enough soap to wash my hands or vagina	Poor loading and removed for length. Focus on menstrual-specific concerns prioritised.
19	I felt clean during my last period	May reflect internalized stigma more than experience of hygiene/menstrual practices. Viewed as value-laden and removed.
20	(r) I worried about where to dispose of my used menstrual materials	Removed for length, items 22, 23, 24 concern disposal.
21	(r) I worried that people, or animals, may be able to access my used menstrual materials after I disposed of them	Removed for length and to reduce number of disposal items, represented by 22.
32	(r) When at home, I worried that someone would see me when I was washing my vagina	Removed for length and to maintain focus on menstrual experience rather than broader washing. Loaded with other privacy concerns. Small cross-load with household facilities (0.20).
33	When at home, I felt comfortable using the same location for urination as when I do not have my period	Urinating in the same location loads with home and school urination items, but not well with other items, poor pairwise correlation with other items except urination items. Remove for scale parsimony.
34	(r) When at home, I worried that others would see my menstrual blood after I had urinated	If many girls do not use latrines when menstruating this question likely to poorly differentiate (those not worrying may be those avoiding usual locations). Loads with school-based urination item.
37	When at school, I felt comfortable using the same location for urination as when I do not have my period	As for 33.
38	(r) When at school, I worried that others would see my menstrual blood after I had urinated	Removed as for item 34, differential responding based on location use and poor loading.
Items relevant to those washing and reusing materials		
48	(r) I worried about how I would get soap to wash my menstrual materials	Excluded for poor loading in EFA.
52	I was satisfied with the place I used to dry my menstrual materials	Removed for scale length.
53	I was satisfied with the appearance of my menstrual materials after I had cleaned them	Rated poorly by FGDs with enumerators in Niger. Concerns of shaming or respondents not answering honestly.
54	I was satisfied with the smell of my menstrual materials after I had cleaned them	
(r) reverse coded		

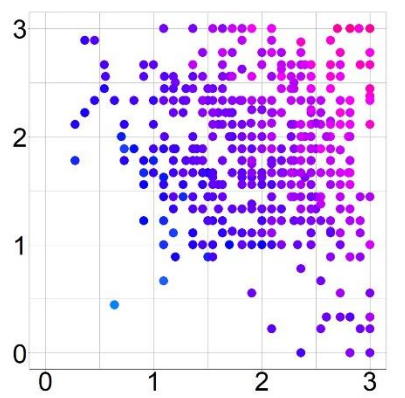
Supplementary Materials 3

Relationship between subscale scores (x axis, y axis) and total MPNS score (colour)

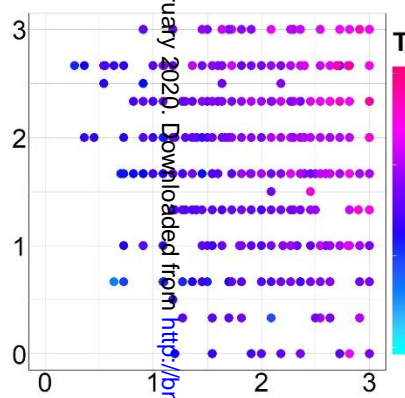
Material and home environment needs and Transport and school environment needs



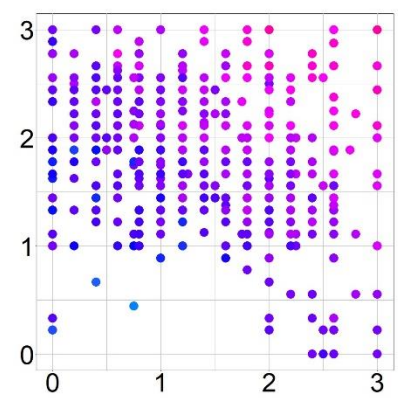
Material and home environment needs and Change and disposal insecurity



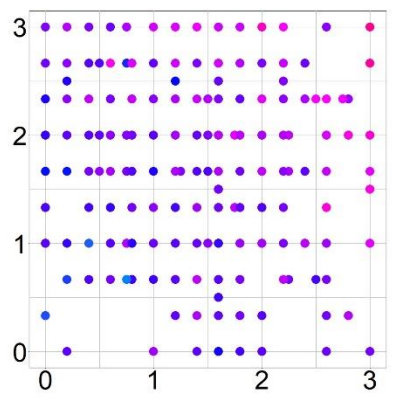
Material and home environment needs and Material reliability concerns



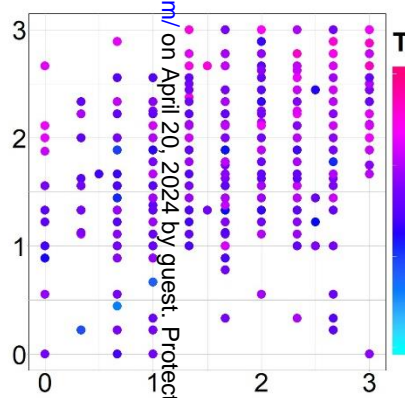
Transport and school environment needs and Change and disposal insecurity



Transport and school environment needs and Material reliability concerns



Material reliability concerns and Change and disposal insecurity



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Supplementary Materials 4

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Title
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction (pg. 4-5)
Objectives	3	State specific objectives, including any prespecified hypotheses	Scale development, Introduction Paragraph 6
Methods			
Study design	4	Present key elements of study design early in the paper	Abstract + Methods "Instrument evaluation"
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Method, "Instrument evaluation" Paragraph 1
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	"Instrument Evaluation" Paragraph 2-4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	"Survey content and question format"
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	"Survey content and question format"
Bias	9	Describe any efforts to address potential sources of bias	Instrument evaluation: Analyses
Study size	10	Explain how the study size was arrived at	"Study sample and data collection" Paragraph 1.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	"Instrument evaluation: Analyses" (starts page 9)
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Instrument evaluation: Analyses
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	Instrument evaluation: Analyses
		(d) If applicable, describe analytical methods taking account of sampling strategy	NA
		(e) Describe any sensitivity analyses	Instrument evaluation: Analyses

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Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results – “Participants”
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results – “Participants”
		(b) Indicate number of participants with missing data for each variable of interest	Results “Item responses”
Outcome data	15*	Report numbers of outcome events or summary measures	Table 4
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	“Dimensionality” “Reliability” “Validity”
		(b) Report category boundaries when continuous variables were categorized	NA
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	“Dimensionality” “reliability”
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion, paragraph 1-3
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion – “Strengths and Limitations”
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussions – “Implications for research and practice”
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion “Strengths and Limitations”
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding statement (pg. 22) and journal submission system.

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.