A new technique to measure online bullying: online computerized adaptive testing

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Abstract
Background: Workplace bullying has been measured in many studies to investigate mental health issues. None uses online computerized adaptive testing (CAT) with cutting points to report bully prevalence at workplace.
Objective: To develop an online CAT to examine person being bullied and verify whether item response theory-based CAT can be applied online for nurses to measure exposure to workplace bullying.
Methods: A total of 963 nurses were recruited and responded to the 22-item Negative Acts Questionnaire-Revised (NAQ-R). All non-adaptive testing (NAT) items were calibrated with the Rasch rating scale model. Three scenarios (i.e., NAT, CAT, and the randomly selected method to NAT) were manipulated to compare their response efficiency and precision by comparing (i) item length for answering questions, person measure, (ii) correlation coefficients, (iii) paired t tests, and (iv) estimated standard errors (SE) between CAT and the random to its counterpart of NAT.
Results: The NAQ-R is a unidimensional construct that can be applied for nurses to measure exposure to workplace bullying on CAT. CAT required fewer items (≈8.9) than NAT (≈22, an efficient gain of 60% ≈1–8.9/22). Nursing measures derived from both tests (CAT and the random to NAT) were highly correlated (r = 0.93 and 0.96) and their measurement precisions were not statistically different (the percentage of significant count number less than 5%) as expected, but CAT earns smaller person measure SE than the random scenario. The prevalence rate for nurses was 1.5% (≈15/963) when cutting points set at −0.7 and 0.7 logits.
Conclusion: The CAT-based NAQ-R reduces respondents' burden without compromising measurement precision and increases endorsement efficiency. The online CAT is recommended for assessing nurses using the criteria at −0.7 and 0.7 (or <30 and <60 in summed score) to identify bully grade as one of the three levels (high, moderate, and low). The bullied nurse can get help from a psychiatrist or a mental health expert at an earlier stage.
Keywords: Computerized adaptive testing, Non-adaptive testing, Item response theory, The Negative Acts Questionnaire-Revised, workplace bullying

Background
During the last 20 years, the prevalence rate of workplace bullying has been reported in a range of different studies to investigate mental health issues [1–3]. Despite all this attention on the bully phenomenon, the criteria of cutting points indeed influence the calculation of prevalence rate on workplace bullying. The prevalence rate of bullying, using the same bully scale of the 22-item Negative Acts Questionnaire-Revised (NAQ-R) with examinee's self-labeling (i.e., with a single quest to answer whether she/he is a bullied victim [4, 5]), was, respectively, reported at 24% for hospital nurses [2], higher than seen in studies of Japanese nurses (19%) [3], and Italian employees (15.2%) [4], and workers in general services (2–17%) [1]. Nielsen et al. [6] addressed that self-labeling with definition studies yielded far lower estimates of bullying than self-labeling studies without definitions. The findings for the prevalence rate on workplace bullying would be thus biased and overestimated without definitions when self-labeling bullied perception.
Common cutting points are required
For studies using the behavioral method (i.e., with several items to respond with regard to encountered negative acts or behaviors in a workplace [1, 7], like the NAQ-R) with an operational criterion, prevalence rates seem to vary between 3 and 17%, depending on the cutoff criterion utilized [8]. Unfortunately, no such a common cutting point for calculating the bully prevalence rate was applied to the NAQ-R till now. A comparison between derived score levels and the suggested best cutoff points can help clinicians evaluate examinees at risk of an incidence [9, 10], and multiple cutoff points are usually more powerful and useful than one single cutoff point [11, 12]. How to determine appropriate cutting points for the NAQ-R is an issue of the current study.

Cutting points are required for computerized adaptive testing
The NAQ-R is evident of a unidimensional construct and can be applied to measure exposure to workplace bullying through the computerized adaptive testing (CAT) administration [2]. The CAT requires fewer items to answer than the traditional pen-and-paper approach (an efficiency gain of 32%), suggesting a reduced burden for respondents [2]. However, the CAT-based NAQ-R is just administered on a computerized nursing cart (i.e., not an online CAT version) and is not set with multiple cutting points to help clinicians evaluate examinees at risk of an incidence, especially because each person answers a different number of items on the CAT. Determining cutting points is thus a critical issue for the NAQ-R CAT.

Computerized adaptive testing
Computerized adaptive testing (CAT) is based on item response theory (IRT)_test that adapts to the examinee’s ability level. The computer follows an IRT-based algorithm that offers the patient the next not-too-hard-and-not-too-easy item. So, only the fewest possible items are offered per patient, resulting in less respondent burden and even more accurate outcomes [2]. As with all forms of Web-based technology development, there is no online CAT assessment applied to the NAQ-R till now.

Objectives
First, we verify whether the NAQ-R is a unidimensional construct. Second, we determine a set of cutting points that can be used for computing a prevalence rate at workplace on CAT. Third, we compare CAT with non-adaptive testing (NAT) and the randomly selected method to NAT on efficiency and precision. Fourth, we developed an online CAT for nurses to measure exposure to workplace bullying.

Methods
Study participants
The study sample was recruited from three hospitals (Hospital A: 1236-bed medical center; B: 265-bed local hospital; C: 877-bed region hospital) in southern Taiwan in the summer of 2012. No incentive for participation was offered. A total of 970 copies of the bully questionnaire were validated with a return rate of 96.3%.

This study was approved and monitored by the Research Ethics Review Board of the Chi-Mei Medical Center. Demographic data were anonymously collected: gender, work tenure in hospitals of all types, age, marital status, and education level.

Scales used for reporting exposure to bullying
The 22-item NAQ-R with 5 response alternatives (1 = never, 2 = occasionally, 3 = monthly, 4 = weekly, 5 = daily) was used to measure exposure to workplace bullying within the past 6 months. With permission from the author [13], the NAQ-R was professionally translated into Chinese by authors in Taiwan using a back-translation technique (English–Chinese–English).

Dimensionality
Tennant and Pallant [14] suggested three steps that should be applied to assess scale unidimensionality: (1) conduct prior testing using Horn’s parallel analysis [15] for ensuring that unidimensionality is retained, (2) use Rasch [16] fit statistics ranging from 0.5 to 1.5 [17, 18] to determine the usefulness of the one-dimensional scaling, and (3) run post hoc tests using Rasch standardized residual loading [19] (i.e., $|Z| < 2.0$) across items to inspect the convergent validity, and Smith [20] independent $t$ tests to compare estimates of the percentages (<5%, within ±1.96) and verify invariance of Rasch model. A dimension coefficient (>0.67, DC) suggested by Chien [21] was used for identifying a single-dimensional scale. Point-biserial correlation coefficients on items (PTME, the Pearson correlation between the observations of an item and the item difficulties that is like factor loading in exploration factor analysis) >0.40 was reported to support scale dimensionality.

Cutting points used for the NAQ-R
According to the literature [22–24], as a scale’s reliability (i.e., Cronbach’s α) increases, so does the person-number of ranges that can be confidently distinguished. Measures with reliabilities of 0.67 will tend to vary within two groups that can be separated with 95% confidence; 0.80 will vary within three groups; 0.90, within four groups; 0.94, within five groups; 0.96, within six groups; 0.97, within seven groups; etc. [25].
More conservative to compute the number of the strata, the scale reliability was referred to the Rasch person separation reliability, and then referred to the Rasch threshold difficulty guideline [26] with an appropriate distance between two thresholds ranging from 1.4 to 5.0 logits.

An equal sample size in each stratum suggested by Maslach et al. [27] was applied to determine cutting points. Accordingly, a threshold at zero logits is suggested for two strata, $-0.7$ and $0.7$ ($=1.4 - \logit$ difference with probabilities at 0.33 and 0.67 $=1 - \exp (-0.7)/[1 + \exp (-0.7)]$ for three strata, $-1.1, 0.0,$ and $1.1 (=1.1 - \logit$ difference with probabilities at 0.25, 0.50, and 0.75 $=1 - \exp (-1.1)/[1 + \exp (-1.1)]$ for four strata, and $-1.4, -0.4, 0.4$ and $1.4 (=1.0 - \logit$ difference with probabilities at 0.20, 0.40, 0.60 and 0.80 $=1 - (-1.4)/[1 + \exp (-1.4)]$ for five strata.

Comparison of efficiency and precision using CAT algorithm

Three scenarios (i.e., NAT, CAT, and the randomly selected method to NAT) were manipulated to compare their response efficiency and precision by comparing (i) item length for answering questions, person measure, (ii) correlation coefficients and (iii) Smith’s paired $t$ tests [20], and (iv) estimated standard errors (SE) between CAT and the random to its counterpart of NAT (Fig. 1).

We ran an author-programed VBA (Visual Basic for Applications) module in Microsoft Excel. Rasch person separation reliability yielded from the NAQ-R of the study by Winsteps (i.e., excluding all extreme scores summed to zero) was used to determine the CAT termination criterion using the standard error of measurement (SEM $= SD \sqrt{1 - \text{reliability}}$). Another termination criterion is the mean of the last five change differences between the pre- and post-estimated abilities on each CAT <0.05.

The minimum number of questions required for completion was set at 7 (7/22 items on NAQ-R item length = 30%). The first item was randomly selected from the 22 items when starting the CAT. The provisional measures were estimated by the maximum log-likelihood estimation (MLE). The next question selected was the one with the most information obtained from the remaining unanswered items, interacting with the previously provisional person measures.

An online CAT was designed for smart phones

An online CAT was designed for examinees to report their bully scores in a unit of logit (log odds). The 22 items with their threshold difficulties (calibrated by Rasch Winsteps) and their responsive audios and pictures were uploaded to the website. The rules of the first and the next selected CAT item and the termination criteria are like the aforementioned simulation method.

Statistical tools and data analyses

SPSS 15.0 for Windows (SPSS Inc., Chicago, IL) and MedCalc 9.5.0.0 for Windows (MedCalc Software, Mariakerke, Belgium) were used to calculate (1) Cronbach’s $\alpha$, (2) dimension coefficients, and (3) correlation coefficients between estimated person measures for CAT and the random to its counterpart of NAT. Independent $t$ tests were used to compare (4) the ratios of the different paired person measures. Rasch Winsteps was used for producing (5) person separation reliability. The prevalence rate of workplace bully is calculated by the formula ($=\text{the number of bullied grade excluded from the low stratum divided by the sample}$).

Results

The sample of 963 nurses was obtained from the study. The mean age of the participants was 32.7 ($\pm 5.8$) years, 96% ($n = 924$) were female, and >57.5% ($n = 554$) were unmarried (Table 1).

Dimensionality

The NAQ-R can be unidimensional because

1. one factor was extracted using parallel analysis;
2. all Infit and Outfit mean squares for the 22 items are in a range of 0.5–1.5 (in the Infit column in Table 2; Fig. 2);
3. item loadings from the Rasch PCA of residuals on the first contrast are standardized (i.e., $(\text{loading} - \text{mean})/SD$) within $-1.24$ and 1.57 (within $\pm 2.0$ in the Z column in Table 2); PTME are between 0.51 and 0.74 (in the PTME column in Table 2).
Rasch person separation reliability = 0.84, Cronbach \( \alpha = 0.96 \), DC = 0.88 (>0.67), and Smith's \( t \) test of proportions [20] is near to zero (=1.14% = 11/963 < 5%), see Fig. 3 in panel a. Person measures from CAT did not statistically differ from NAT because (1) Smith's \( t \) test of proportions [20] is 1.6% (=15/963 < 5%), see Fig. 3 in panel b, and (2) correlation coefficient = 0.93 (=\( \sqrt{0.87} \), see Fig. 3 in panel c). As compared to the random scenario, CAT earns a set of smaller SE, see Fig. 3 in panel d.

**Online NAQ-R assessment**

By scanning a QR-code (Fig. 4 at right bottom), the NAQ-R item appears on the smartphone. We developed an online CAT module to demonstrate the assessment in action. The CAT processed each nurse item-by-item with picture animations (Fig. 4 at top). Adaptive item selection is based on maximizing information across unanswered items. The measurement of standard error (MSE) for each subscale decreased when the number of the items increased (Fig. 4). The result with a person measure and the bully grade (i.e., low, moderate, or high) instantly shows on smartphone (Fig. 4).

**Discussion**

**Key findings**

The results from this study indicate that the 22-item NAQ-R is unidimensional. A set of cutting point at \(-0.7\) and \(0.7\) logits were determined for future use in workplace bullying surveys. The prevalence of bullying for the study sample was 1.5%. The CAT is 60% more efficient for answering questions and achieved similar precision in measurements as did NAT. An available-for-download online CAT NAQ-R APP for nurses was suited for smartphones (Additional file 1).

**What this adds to what was known**

Consistent with the literature [2, 28–32], the 22-item NAQ-R can be unidimensional. The efficiency of CAT over NAT was supported. We confirm that CAT-based NAQ-R requires significantly fewer answered items to measure explosion of workplace bully than NAT without compromising its measurement precision.

**What it implies and what should be changed?**

**Cutoff point recommended for calculating bully prevalence rate**

According a study in Belgian employees [33], six different groups of respondents were identified based on their exposure to negative behaviors: (1) not bullied (35%), (2) limited work criticism (28%), (3) limited negative...
encounter (17%), (4) sometimes bullied (9%), (5) work-related bullying (8%), and (6) victims of bullying (3%). Too many grades is hard to help clinicians evaluate examinees at risk of an incidence [9, 10]. A single cut point of >–4.2 logits (or >30 in summation) for the NAQ-R was proposed [2]. However, multiple cutoff points are usually more powerful and useful than one single cutoff point [11, 12]. Maslach et al. [27] suggested setting an equal sample size in each stratum as a way to determine cutting points. At the end of 2016, more than 10,977 papers were found in a search with keyword “cut point.” None discussed the determination of cutting points used for CAT with different item lengths for a respondent. Frequently, we usually do not know the patient’s true- and false-positive disease-specific status, like the NAQ-R. The issue we face in clinical settings is how to identify the degree of patient incident problems. Through this study, if cutting points at −0.7 and 0.7 logits are selected for the NAQ-R, the raw score in cutting points can be transformed by the formula (\(=\text{total score} \times \text{the probability at } 0.33 \text{ and } 0.67\)), whereas 0.33 comes from the equation \(\exp (-0.7) / (1 + \exp (-0.7))\) and 0.67 is from the equation \(1 - \exp (-0.7) / (1 + \exp (-0.7))\), total score = 88 when 5-point (from 0 to 4) 22-item NAQ-R is defined beforehand. The cutting points in raw score can be set at <30 (=88 \times 0.33), and \(\geq 60 (=33 \times 0.67)\) to separate three strata in bullying degree. The prevalence rate is easy to calculated and compared either with paper-and-pen format or with CAT in future.

### Online CAT assessment

At the end of 2016, 757 papers were collected in US National Library of Medicine National Institutes of Health (pubmed.org) when searching keywords: computer adaptive testing. None was applicable using an

| Item                                                                 | Feature | Difficulty | MNSQ | loading |
|----------------------------------------------------------------------|---------|------------|------|---------|
| Type \(=\) (1) work-related bullying; (2) Person-related bullying; (3) physically intimidating bullying |

#### Table 2 One factor extracted from the Negative Acts Questionnaire-Revised (NAQ-R) scale with mean square between 0.50 and 1.50

During the last 6 months, how often have you been subjected to the following negative acts in the workplace?

- 21. Being exposed to an unmanageable workload
- 22. Threats of violence or physical abuse or actual abuse
- 9. Intimidating behaviors such as finger-pointing, invasion of personal space, shoving, blocking your way
- 8. Being shouted at or being the target of spontaneous anger
- 19. Pressure not to claim something to which by right you are entitled
- 3. Being ordered to do work below your level of competence
- 18. Excessive monitoring of your work
- 5. Spreading of gossip and rumors about you
- 15. Practical jokes carried out by people you don’t get along with
- 16. Being given tasks with unreasonable deadlines
- 14. Having your opinions ignored
- 20. Being the subject of excessive teasing and sarcasm
- 2. Being humiliated or ridiculed in connection with your work
- 17. Having allegations made against you
- 6. Being ignored or excluded
- 12. Being ignored or facing a hostile reaction when you approach
- 11. Repeated reminders of your errors or mistakes
- 10. Hints or signals from others that you should quit your job
- 1. Someone withholding information which affects your performance
- 13. Persistent criticism of your errors or mistakes
- 4. Having key areas of responsibility removed or replaced with more trivial or unpleasant tasks
- 7. Having insulting or offensive remarks made about your person, attitudes, or your private life

| Item                                                                 | Difficulty | MNSQ | loading |
|----------------------------------------------------------------------|------------|------|---------|
| Minimum                                                             | −1.29      | 0.76 | −1.24   |
| Maximum                                                             | 1.50       | 1.30 | 1.57    |

Threshold difficulties are −3.26, −0.71, 0.71, 3.25

* Type: (1) work-related bullying; (2) Person-related bullying; (3) physically intimidating bullying
Fig. 2 Item and person dispersion on an interval logit continuum scale
online assessment suited for smartphones until the online skin cancer CAT was published [32]. We do ensure that more papers in future will be published on the usefulness of online CAT as with all forms of Web-based technology are rapidly increasing [34].

**Unidimensional scale detection**
Many studies [21, 35–38] reported the issue of scale unidimensionality detection. From the Library of PubMed and BioMed Central, we got 1005 and 333 papers with the keyword “unidimensionality,” 4688 and 745 results for “bully.” In the current study, we demonstrated the method Tennant and Pallant [14] suggested using three steps to assess scale unidimensionality: (1) conduct prior testing using Horn’s parallel analysis, (2) use Rasch fit statistics, and (3) run post hoc tests using Rasch standardized residual loading, and Smith [20] independent t tests to compare estimates of the percentages (<5%, within ±1.96). In addition, the dimension coefficient (≥0.67, DC) and PTME (>0.40) included in detecting scale unidimensionality are recommended to readers.

**Strengths of this study**
Four goals have been reached in this study: (1) we verified the 22-item NAQ-R is unidimensional, (2) cutting points at −0.7 and 0.7 logits were recommended to future studies in computing bully prevalence rate at workplace, (3) CAT gains 60% efficient than did NAT, and (4) online CAT is applicable in practice. Among them, the reason for 60% efficient than did NAT is because we added another termination rule in CAT: the mean of the last five change differences between the pre- and post-estimated abilities on each CAT less than 0.05. The termination rule of detecting the last five change differences in estimated abilities less than 0.05 makes the item length less than that in other studies [2, 28–31]. It is because many low grade of workplace bully were found and led to short item length required to complete the CAT. Around 82.6%
Fig. 4 A snapshot of online CAT-based NAQ-R assessment
Valid criteria are thus urgently required to classify lev-
every week in the past 6 months. Another used an
bullying if subjects had experienced at least 2 of the 22
to different cutting points and self-labeling definitions.
seen in studies of Greek nurses (30.2%) [39], Japanese
ian employees (15.2%) [4], and workers in general ser-
in services (2–17%) [1]. One ensured reason is attributable
to different cutting points and self-labeling definitions. For
instance, one [40] defined a victim of workplace bullying if subjects had experienced at least 2 of the 22 negative acts from NAQ-R by a colleague every day or every week in the past 6 months. Another [39] used an additional question “Have you been bullied at work?”. Valid criteria are thus urgently required to classify levels of incidence and to calculate the prevalence rate of workplace bullying. Accordingly, the study cannot be gen-
eralized to others.

More studies are needed to assess the generalizability of the study with different samples using the same cutting points and the same version of NAQ-R. Third, the online CAT is not equipped with much functionality as we expected in practice, such as protecting cheating behaviors and detecting aberrant responses that are required to be in future advanced versions. Fourth, although the scale’s Cronbach’s α coefficients was 0.96, we conserva-
tively determined that the scales’ person strata were three according to Rasch separation reliability = 0.84 and the
literature [22–25]. Multiple cutoff points are not lim-
ited to three strata if the separation index reaches an extremely higher level, which will affect the determina-
tion of appropriate cutting points for the NAQ-R.

**Conclusions**
The CAT-based NAQ-R forming a unidimensional con-
struct reduces respondents’ burden without compromis-
ing measurement precision and increases endorsement
 efficiency. The online NAQ-R module developed by the
authors is recommended for assessing nurses or other
workers using the criteria at −0.7 and 0.7 (or <30 and <60
in summed score) to identify bully grade as one of the
three levels (high, moderate, and low). The bullied nurse
can get help from a psychiatrist or a mental health expert
at an earlier stage.

**Additional file**

**Additional file 1.** Online bully CAT video at https://youtu.be/te9Gmpi9q8w.

**Abbreviations**
APP: application; CAT: computer adaptive testing; CTT: classic test theory; DC: dimension coefficients; DIF: differential item functioning; IRT: item
response theory; MLE: maximum likelihood estimation; MNSQ: mean square; MSE: mean-squared error; NAT: non-adaptive testing; NAQ-R: Negative Acts
Questionnaire-Revised; PCA: principal component analysis; PTME: point-biase-
trial correlation coefficients on measures; SD: standard deviation; SE: standard
error; SEM: standard error measurement; VBA: visual basic for applications.

**Authors’ contributions**
SCM developed the study concept and design. TWC and SCM analyzed and
interpreted the data. HHW monitored the process of this study and help
responded to the reviewers’ advices and comments. TWC drafted the manu-
script, and all authors provided critical revisions for important intellectual
content. The study was supervised by TWC. All authors read and approved the
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**Competing interests**
The authors declare that they have no competing interests.

**Availability of data and materials**
This research is based on a simulation study. All codes and data can be
obtained from those in additional files of this study.

**Declarations**
We thank Frank Bill who provided medical writing services to the manuscript.

**Ethics approval and consent to participate**
This study was approved and monitored by the Research Ethics Review
Board of the Chi-Mei Medical Center. Demographic data were anonymously
collected: gender, work tenure in hospitals of all types, age, marital status, and
education level.
1. Nielsen MB, Notelaers G, Einarsen S. Measuring exposure to workplace bullying. In: Einarsen S, Hoel H, Zapf D, Cooper CL, editors. Bullying and harassment in the workplace: developments in theory, research, and practice. Boca Raton: Boca Raton CRC Press; 2011. p. 149–76.

2. Ma SC, Chien TW, Wang HH, Li YC, Yui MS. Applying computerized adaptive testing to the negative acts questionnaire-revised: Rasch analysis of workplace bullying. J Med Internet Res. 2014;16(2):e50.

3. Abe K, Henly SJ. Bullying (ijime) among Japanese hospital nurses: modeling responses to the revised Negative Acts Questionnaire. Nurs Res. 2010;59(2):110–8.

4. Giorgi G, Arenas A, Leon-Perez JM. An operative measure of workplace bullying: the negative acts questionnaire across Italian companies. Ind Health. 2011;49(6):686–95.

5. Einarsen S. Bullying and harassment at work: epidemiological and psychosocial aspects. Bergen: University of Bergen; 1996.

6. Nielsen MB, Mattijsen SB, Einarsen S. The impact of methodological moderators on prevalence rates of workplace bullying: a meta-analysis. J Occup Organ Psychol. 2010;83(4):955–79.

7. Einarsen S, Hoel H, Notelaers G. Measuring bullying and harassment at work: validity, factor structure, and psychometric properties of the Negative Acts Questionnaire-Revised. Work Stress. 2009;23(1):24–44.

8. Nielsen MB. Methodological issues in research on workplace bullying: operationalisations, measurements, and samples. Unpublished doctoral dissertation, University of Bergen, Norway; 2009.

9. Hwang AW, Chou YT, Hsieh CL, Hsieh WS, Liao HF, Wong AM. A developmental screening tool for toddlers with multiple domains based on Rasch analysis. J Formos Med Assoc. 2015;114:23–34.

10. Chien TW, Lin WS. Simulation study of activities of daily living functions using online computerized adaptive testing. BMC Med Inform Decis Mak. 2016;16(1):130.

11. Stitrau E, Richardson WS, Glaszoon P, Haynes RB. Evidence-based medicine: how to practice and teach EBM. 3rd ed. London: Elsevier Churchill Livingstone; 2005.

12. Liao HF, Yau G, Chien CC, Cheng LY, Hsieh WS. Likelihood ratios of multiple cutoff points of the Taipei City Developmental Checklist for Preschoolers, 2nd version. Formosan J Med. 2014;113(3):179–86.

13. Einarsen S, Skogstad A. Bullying at work: epidemiological findings in public and private organizations. Eur J Work Organ Psychol. 1996;5(3):185–201.

14. Tennant A, Pallant JF. Unidimensionality matters! (A tale of two Smiths?). Rasch Meas Trans. 2006;20(1):1048–51.

15. Horn JL. A rationale and test for the number of factors in factor analysis. Psychometrika. 1965;30(2):179–85.

16. Rasch G. Probabilistic models for some intelligence and achievement test. Copenhagen. Danish Institute for Educational Research, 1960.

17. Linacre JM. User's Guide to Winsteps. Chicago. Mesa Press; 2010.

18. Bond TG, Fox CM. Applying the Rasch model: fundamental measurement in human sciences. 2nd ed. Mahwah: Lawrence Erlbaum; 2007. p. 179.

19. Linacre JM. Structure in Rasch residuals: why principal components analysis (PCA). Rasch Meas Trans. 1998;12(2):636.

20. Smith EV. Detecting and evaluating the impact of multidimensionality using item fit statistics and principal component analysis of residuals. J Appl Meas. 2002;3(2):205–31.

21. Chien TW. Cronbach’s a with the dimension coefficient to jointly assess a scale’s quality. Rasch Meas Trans. 2012;26(3):1379.

22. Fisher W Jr. Reliability, separation, strata statistics. Rasch Meas Trans. 1994;6(3):238.

23. Wright BD, Masters GN. Number of person or item strata. Rasch Meas Trans. 2002;16(3):888.

24. Wright BD. Reliability and separation. Rasch Meas Trans. 1996;9(4):472.

25. Fisher WP Jr. The cash value of reliability: Rasch Meas Trans. 2008;22(1):1160–3.

26. Linacre JM. Optimizing rating scale category effectiveness. J Appl Meas. 2002;3(1):85–106.

27. Maclachlan C, Schaufeli WB, Leiter MP. Job burnout. Ann Rev Psychol. 2001;52:397–422.

28. Chien TW, Wang WC, Huang SY, Lai WP, Chow JC. A web-based computerized adaptive testing (CAT) to assess patient perception in hospitalization. J Med Internet Res. 2011;13(3):e61.

29. Chien TW, Wu HM, Wang WC, Castillo RV, Chou W. Reduction in patient burdens with graphical computerized adaptive testing on the ADL scale: tool development and simulation. Health Qual Life Outcomes. 2009;7:39.

30. Wainer HW, Dorans NJ. Computerized adaptive testing: a primer. Hillsdale: L Erlbaum Associates; 1990.

31. Embretson S, Reise S, Reise SP. Item response theory: principles and practice. Mahwah: L Erlbaum Associates; 2000.

32. DJaja N, Janda M, Olsen CM, Whiteman DC, Chien TW. Estimating skin cancer risk: evaluating mobile computer-adaptive testing. J Med Internet Res. 2016;18(1):e22.

33. Notelaers G, Einarsen S, De Witte H, Vermunt J. Measuring exposure to bullying at work: the validity and advantages of the latent class cluster approach. Work Stress. 2006;20(4):288–301.

34. Mitchell SJ, Godoy L, Shabazz K, Horn IB. Internet and mobile technology use among urban African-American parents: survey study of a clinical population. J Med Internet Res. 2014;16(1):e9.

35. Smith RM. A Comparison of methods for determining dimensionality in Rasch measurement. Struct Equ Model. 1996;3:25–40.

36. Zwicker WR, Velicer WF. Comparison of the rules for determining the number of components to retain. Psychol Bull. 1986;99:432–42.

37. Wright BD. Unidimensionality coefficient. Rasch Meas Trans. 1994;8(3):585.

38. Linacre JM. Rasch measures and unidimensionality. Rasch Meas Trans. 2011;24(4):1310.

39. Karatzas C, Zygka S, Tzafiri S, Prezerakos P. Workplace bullying and general health status among the nursing staff of Greek public hospitals. Ann Gen Psychiatry. 2016;15:7.

40. Yun S, Kang J, Lee YO, Yi Y. Work environment and workplace bullying among Korean intensive care unit nurses. Asian Nurs Res. 2014;8(3):219–25.