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Using graphical representations to enhance the quality-of-care for colorectal cancer patients

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The study was to enhance adherence to quality-of-care guidelines for colorectal cancer (CRC) patients through plotting graphical representations. Rasch analysis was performed to examine the unidimensional measurement of the 13 core indicators. An author-made Excel module was applied to plot the so-called Wright map and KIDMAP in education field to report physicians' adherence to the quality-of-life guidelines. We found that the scale of the quality-of-care guidelines for patients with colon cancer is unidimensional. A total of 15 (3.8%) and 14 (3.5%) persons' response patterns (i.e., Outfit MNSQs >2.0 and 4.0, respectively) are aberrantly dispersed from the majority of sample according to their estimated parameters of persons and indicators. It can be used for investigating the root cause of the 1ow measures and/or the most unexpected aberrant pattern of responses using Rasch analysis once any one indicator of unexpectedly aberrant treatment ($p < .05$) presents. The Rasch model can deal with these binary and/or missing data frequently seen in clinical settings. We confirm this computer module can contribute to ensuring that hospitals adhere to the treatment guidelines for patients with colon cancer.

KEYWORDS
colorectal cancer, KIDMAP, Rasch model, unidimensionality, Wright map

1 | INTRODUCTION

Colorectal cancer (CRC) is the third most common cancer in males and the second in females (Akhtar, Chandel, Sarotra, & Medhi, 2014). It is a malignant neoplasm arising from the lining of the large intestine (colon and rectum). The estimated new cases of colon cancer and rectal cancer in the United States in 2009 were 106,100 and 40,870 respectively (Le et al., 2014). CRC is the third leading cause of cancer-related death worldwide, with over 900,000 diagnoses and 639,000 deaths each year (Leon-Carlyle et al., 2009).

Approximately 40,340 new cases of rectal cancer in 2013 were diagnosed in the United States (Siegel, Naishadham, & Jemal, 2013). The highest incidence rates are in Australia, New Zealand, Canada, the United States and parts of Europe, whereas China, India, parts of Africa and South America have the lowest risk of colorectal cancer in the world (Jemal et al., 2011).

Sixty per cent of these CRC patients present with stage II or III disease, which recurs with metastatic or locally invasive disease in approximately 35%–40% of patients (Arends, 2010; Jonsson, Stenberg, & Frisman, 2010). Treatment for CRC varies by tumour location and stage at diagnosis. However, the surgical removal of the tumour and nearby lymph nodes is the most common treatment for early stage (stage I or II) of colorectal cancers (Akhtar et al., 2014). Patients with late-stage disease are often treated with chemotherapy alone or in combination with radiation therapy before or after surgeries (Akhtar et al., 2014). In spite of these different treatment rendered in clinical settings, the survival rate for colorectal cancer varies with stage of disease at diagnosis and typically varies from 90% for cancers detected at the localised stage to 10% for distant metastatic cancer (Jemal et al., 2004; Steele et al., 2014).

On the other hand, many studies (Chien, Lin, Chang, Tsai, & Uen, 2012; Chung et al., 2008; Malin, Asch, Kerr, & McGlynn, 2000; Mandelblatt, Ganz, & Kahn, 1999; Spencer, Steinberg, Malin, Adams, & Litwin, 2003) who advocate patient quality of care have claimed that physician adherence to quality-of-care indicators improves cancer patients' treatment outcomes. Plotting objective graphical representations is required to help monitor physician performance, which

improves the rate of adherence to quality-of-care guidelines for CRC patients. Management thinker Peter Drucker is often quoted as saying that "you can't manage what you can't measure." Another similar and famous phrase, "One Look Is Worth A Thousand Words," appears in a 1913 newspaper advertisement for the Piqua Auto Supply House of Piqua, Ohio in US, and attracts us to demonstrate a way through graphical representations to enhance the quality-of-care for colorectal cancer patients.

The problem we encountered is that so many missing responses are frequently occurred in those data of patient quality of care. An inherent weakness of conventional analytical techniques based on classic test theory (CTT), such as the summation of all item scores, is that they require linear, interval scale data input (Wright, 1997). Raw data collected through a dichotomous scale (e.g., 0 = *fail* and 1 = *success* in Tables 1 and 2) are always ordinal because their categories indicate the ordering without any proportional levels of meaning (Bond & Fox, 2007; Wright, 1997). Therefore, using CTT dealing with clinical ordinal data is highly possible to mislead conclusions.

The Rasch model overcomes this problem by converting ordinal data into interval measures, which have a constant interval interpretation and provide objective measurement of dichotomous (0 vs. 1) responses (Linacre, 2015), and successfully dealing with missing data in a survey or a test (Moulton, 2016; Wright & Mok, 2000). We are thus interested in developing an easy-use computer module on Microsoft Excel to show how Rasch interval score are obtained and how graphical representations are plotted for helping improve the rate of adherence to quality-of-care guidelines for CRC patients. Both Wright map (Wilson, 2011) and KIDMAP (Masters, 1994) from Rasch model's perspective are demonstrated in this study.

2 | MATERIALS AND METHODS

The study sample included 708 patients with newly diagnosed colorectal cancer who had been treated between 2004 and 2007 at a 1,300-bed hospital in southern Taiwan. Data from these patients' charts were obtained and approved by the Research Ethics Review Board of the Chi-Mei Medical Center (registry no. C6218) (Chien et al., 2012).

A set of 13 core measures was used to assess adherence to the quality-of-care guidelines for patients with CRC. The 100% adherence rate criterion contributed to a relatively low hazard ratio of 0.36 (95% confidence interval, 0.14–0.85; p = .02) (Chien et al., 2012). The association between the adherence rate and survival indicated significant improvements for stage III patients compared with stage I patients.

TABLE 1 Indicators available for use

		Adherence exclusion in stage							
	13 core indicators	Colon cancer				Rectal cancer			
No.	Description	I	II	III	IV	I	II	III	IV
1	Clinical stage should be reported before surgery								
2	Colonoscopy was done 6 months before and 3 months after surgery				X				X
3	Patients with stage II or III CRC were offered surgical resections within 6 weeks				X	X	X	X	X
4	Histopathology reported degree of involvement of surgical margins & number of lymph nodes for patients with stage I–III CRC				X				X
5	Patients with stage I–III CRC were at negative margin status				X				X
6	Pathological tumour and node stage should be reported after surgery								
7	12 or more lymph nodes were examined in patients with stage I–III CRC				X				X
8	Pathology reports were checked				X				X
9	Patients with COLON stage III were offered surgery within 6 weeks after C/T	X	X		X	X	X	X	X
10	Patients with stage I–III CRC were treated within 6 weeks	X	X	X	X	X			X
11	Patients with stage II or III CRC were offered surgery within 16 weeks after CCRT	X	X	X	X	X			X
12	Treatments were performed within 6 months following 6 months after surgery for newly diagnosed cancer patients with stage I–III CRC				X				X
13	Colonoscopy or LGI was performed 2 years after surgery				X				X

X denotes exclusion of indicator by stage, cancer type and the reasonable discontinuation of treatment, i.e., patients not eligible for the specific procedure.

TABLE 2 A comparison of adherence indexes for individual response patterns

No.	Person responses	Easy – items – hard	Infit	Outfit	Measure	SE
1	Modelled/ideal	1110110110100000	0.66	0.55	−0.01	0.58
2	Guttman/ deterministic	1111111100000000	0.68	0.57	−0.01	0.58
3	Miscode	0000000011111111	2.73	3.91	−0.01	0.58
4	Carelessness/ sleeping	0111111110000000	0.81	0.83	−0.01	0.58
5	Lucky guessing	1111111000000001	0.87	0.85	−0.01	0.58
6	Response set/Miskey	1010101010101010	1.26	1.26	−0.01	0.58
7	Special knowledge	1111000011110000	1.02	0.88	−0.01	0.58
8	Imputed outliers	1111010110010000	0.86	0.74	−0.01	0.58
9	Low discrimination	1110101010101000	0.83	0.70	−0.01	0.58
10	High discrimination	1111110101000000	0.83	0.70	−0.01	0.58
11	Very high discrimination	1111111010000000	0.53	0.45	−0.01	0.58
12	With missing data	..111.111.100.11	0.99	0.65	1.86	0.83
13	With missing data	111.111.111.10.0	0.49	0.26	2.02	0.89
14	With missing data	...00.000.111..0	1.55	1.72	−0.64	0.75
15	With missing data	11.1.00.00.000..	0.60	0.46	−1.12	0.77

The dot (".") refers to a response with a missing datum. SE denotes the standard error of the respective person measure.

Three hundred and ninety-seven patients with colon cancer were extracted from the sample of 708 patients (Chien et al., 2012). Each indicator assigned to each cancer stage was dichotomously coded (shown in Table 1). Physician adherence to core indicators was assessed using the Rasch model (Rasch, 1960).

2.1 | Fit statistics used in Rasch analysis

Rasch analysis has been successfully applied in education and social sciences to address assessment issues (Bond & Fox, 2007; Panayides, Robinson, & Tymms, 2010; Tormakangas, 2011). Once the interval metric is established, person measures and item difficulties are calibrated onto a single unidimensional latent trait (i.e., the level of the quality of care in this study), which facilitates direct comparisons between person measures and item difficulties.

Rasch person fit statistics have also been frequently used in the academic fields of education and psychometric research (Li & Olejnik, 1997; Linacre, 2015; Sijtsma & Molenaar, 2002). Table 2 shows typical dichotomous patterns with missing data. According to the estimated parameters of persons and items, the two mean square errors (MNSQs) of Infit and Outfit for each person can display significantly aberrant behaviours (i.e., whose response pattern different from others; this result requires further investigation and improvement) once the MNSQ is greater than 2.0 (Linacre, 2002; Linacre & Wright, 1994), for instance, person 3 with an Outfit MNSQ 3.91 in Table 2 shows an aberrant abnormality. Furthermore, the Rasch model can offer practical solutions to such a problem of missing data (Fisher, 1995; Ludlow & O'Leary, 1999), like the symbol X shown in Table 1 and the dot responses in Table 2, which are problematic in CTT approaches (Montiel-Overall, 2006; Moulton, 2015; Peugh & Enders, 2004). Interested readers are recommended to see the example of handling missing data using Rasch procedure in an Excel workbook (Moulton, 2016).

2.2 | Graphical representations: Wright map and KIDMAP

In Rasch analysis, we often see researches use the term "item map," "variable map" or "Wright map" to describe the representation of items and persons on the same continuum (Rittle-Johnson, Matthew, Taylor, & McEldoon, 2011; Wilson, 2011). It is acknowledged that Ben Wright of Chicago University had championed this approach to interpreting the results of measurement analyses in the form of between items and persons.

KIDMAP, a personal performance report card that takes the form of within a person related to items, is developed within the context of Rasch measurement and usually used to display academic performance in schools (Chien, Wang, Wang, & Lin, 2009; Chien, Wang, et al., 2009; Wright, Mead, & Ludlow, 1980). A complete KIDMAP highlights the level at which a patient's care meets (or not adhere to) the quality guidelines and pinpoints the strengths and weaknesses of the evaluated doctor's performance (Doig, 1990; Masters, 1994).

Colourful types of Wright map (Chien & Huang, 2015) and KIDMAP (Chien, Linacre, & Wang, 2011) were developed in this study to replace the traditional monochrome one. Besides, a scatter chart is also plotted in which persons' Rasch scores and Outfit MNSQs are shown on two coordination axes displaying the outlier cases aberrantly dispersed from the majority of the sample.

2.3 | Statistical analysis

Rasch analysis using Winsteps 3.8 (Linacre, 2015) was used to compare the results equivalent to the author-made computer module (Chien, 2016) that show the graphical representations of the adherence to quality-of-care guidelines using Wright map and KIDMAP.

3 | RESULTS

The colourful Wright map displayed in Figure 1 shows that all indicators on the right side are dispersed rather well (within the criterion of Infit MNSQ between 0.5 and 1.5), supporting a one-dimensional measurement of the quality-of-care guidelines for patients with colon cancer.

In Rasch analysis, the mean of indicators' difficulties is arbitrarily set to zero logit (i.e., in a unit of log odds along with the far most left vertical values in Figure 1), indicating indicator difficulties and person measures are jointly compared against each other between indicators and persons. Likely, person measures higher than zero indicate a positive response, while person measures lower than zero indicate a negative response. Figure 1 shows that only six persons' measures (=6/397=1.3%) are less than zero, implying that a few persons received care below the quality-of-care guidelines. The reasons for this low quality of care must be further investigated.

An overall patient report card is shown in Figure 2 using scatter chart in line with individuals' coordinates with their Outfits and measures. A total of 15 (3.8%) and 14 (3.5%) persons' response patterns (i.e., Outfit MNSQs >2.0 and 4.0, respectively) are aberrantly dispersed from the majority of the sample according to their estimated parameters of persons and indicators. The reasons for this result must be further investigated as well.

A person whose Outfit MNSQ is higher (=4.1) than the criterion (>2.0) is illustrated in Figure 3. We can see that indicator 4 (with a response of 0) is located on the left side on the *X* axis, implying that indicator 4 (i.e., Histopathology reported degree of involvement of surgical margins and number of lymph nodes for patients with stage I–III CRC) is easy for him/her but not achieved (i.e., coded as 0). The most unexpected indictor with a *Z*-score less than −2.0 is denoted by the function [=(observed−expected)/SD = (0–0.99)/0.001 = −37.86]> *t* test criterion at 1.96, whereas 0.99(= EXP(4.1−(−3.16))/(1 + EXP(4.1−(−3.16))) is the probability to code as 1, and −3.16 is the indicator difficulty shown along with the *Y* axis, and given a statistically significant abnormity against others' performance when the person's quality of care value is 4.1 logits (shown on the top of the vertical axis).

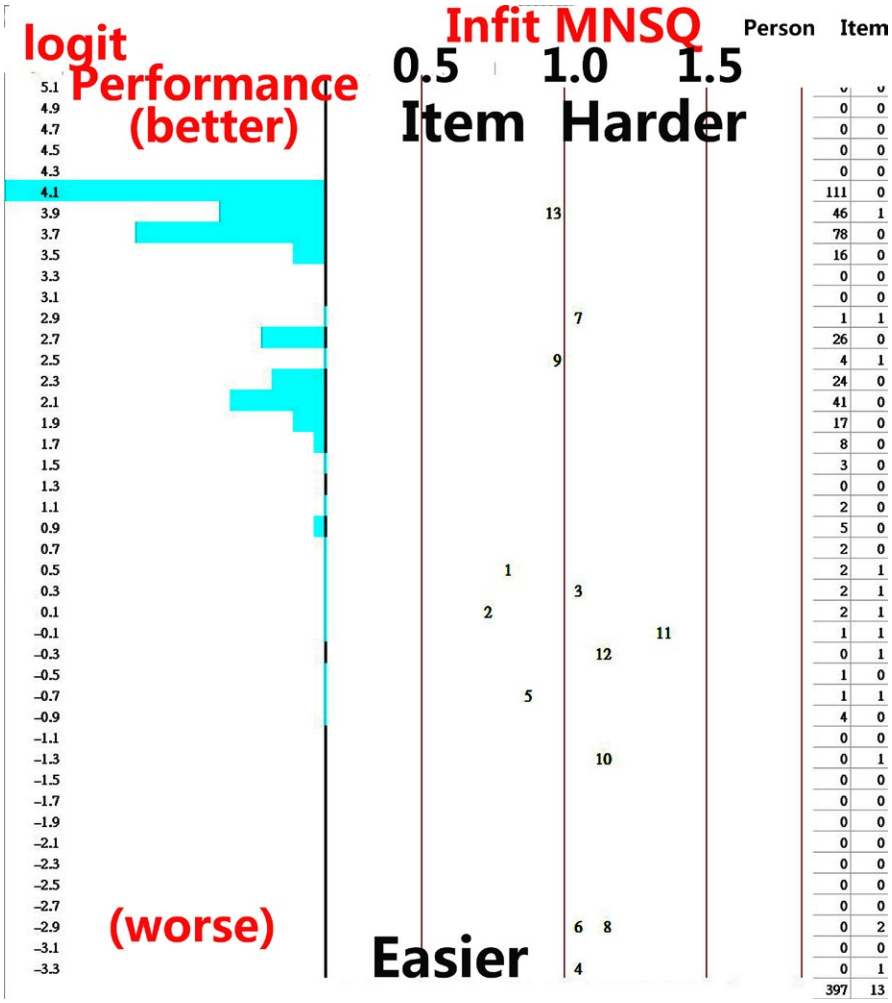

FIGURE 1 All item but item 2 show one-dimensional measurement of the scale using Infit MNSQ statistics

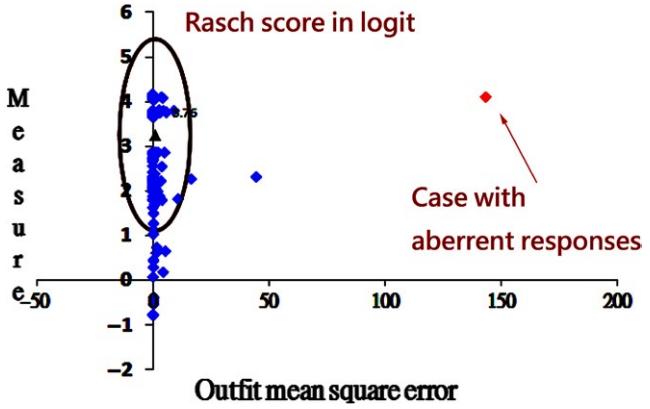

FIGURE 2 The scatter plot show patient individual coordinates with their outfits and measures

4 | DISCUSSION

We found that the scale of the quality-of-care guidelines for patients with colon cancer is unidimensional. A total of 15 (3.8%) and 14 (3.5%) persons' response patterns (i.e., Outfit MNSQs >2.0 and 4.0, respectively) are aberrant and dispersed from the majority of the sample according to their estimated parameters of persons and indicators. It can be used to investigate the root cause of the low measures and/or aberrant pattern of responses through the Rasch Wright map and KIDMAP.

Using a set of 13 quality indicators for the assessment of the quality of cancer patient care, a strong association between physician adherence rates to quality-of-care indicators and colorectal cancer patient survival was found (Cheng et al., 2009; Chien et al., 2012), which complies with previous reports (Cheng et al., 2009; Higashi, Shekelle, & Adams, 2005). It is evident that improving adherence rates will also improve the quality management of cancer health care (Williams, Schmaltz, & Morton, 2005). Accordingly, we programmed an Excel-based module to present patients' quality-of-care guideline measure and Outfit MNSQ on a scatter chart (Figure 2), followed by a between-Wright map against items and persons (Figure 1) and a within-KIDMAP of a person related to indicators (Figure 3).

Such a graphical representation of results is much more useful than the simple bubble charts used for checking performances (Chien et al., 2012). Previously published papers (Chung et al., 2010; Higashi et al., 2005) did not present other effective ways, such as fit statistics in Figures 2 and 3, to improve adherence to quality-of-care guidelines.

More than 80% of medical resources are under physician control (Eldenburg, 1994; Evans, Hwang, & Nagarajan, 2013). One way to change physicians' behaviour is to offer them comparable kinds of information (Eldenburg, 1994). We ensure that this visual representation allows us to attain the rule of "always comparing, always improving quality of care" at the physician level through the feedback reporting process (Chien, Wang, Wang, et al., 2009; Chien, Wang, et al., 2009), which exists to motivate physicians to more closely adhere to the quality-of-care indicators.

For simplicity, we only drew 397 patients with colon cancer from the sample of 708 patients (Chien et al., 2012). The unidimensional scoring scale cannot be generalised to patients with rectal cancer. When the plotting of a Wright map and KIDMAP is applied to any other cancer patients, the preliminary approach of examining and verifying the scale's unidimensionality should be conducted. Another limitation is the need to offer members of cancer treatment teams training to interpret the Wright map and KIDMAP correctly.

Empirically, Rasch analysis has been successfully applied in education and social sciences to address assessment issues (Bond & Fox, 2007; Panayides et al., 2010; Tormakangas, 2011). In clinical practice, many indicators are excluded from the calculation of adherence rates due to issues such as stage, cancer type and the reasonable discontinuation of treatment, i.e., patients not eligible for the specific procedure.

In tradition, many social science researchers apply the exploratory factor analysis or Horn's parallel analysis (Horn, 1965) to assess scale unidimensionality. Those data are subject to continuous variables without missing data. It obviously not complies with dichotomous response variables with many missing responses in this study. Using Rasch fit statistics ranging from 0.5 to 1.5 is to determine the

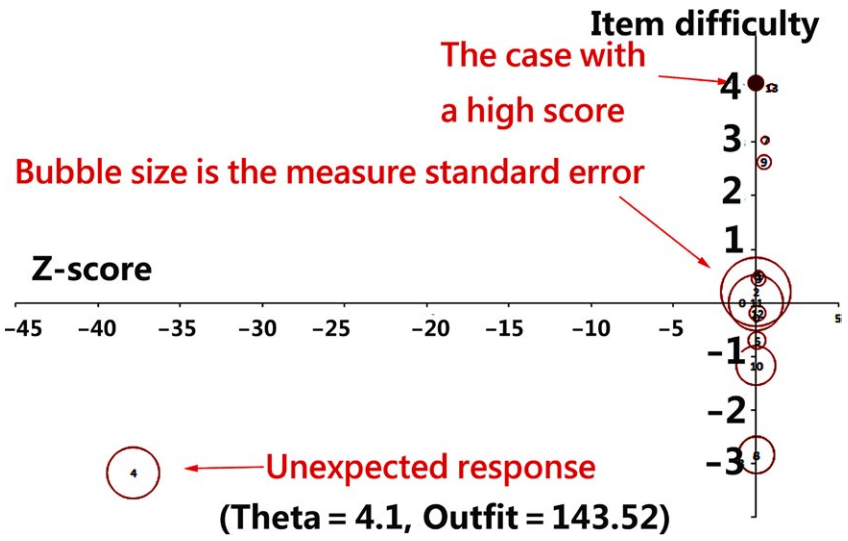

FIGURE 3 The most unexpected indicator shown out of control to the guideline adherence level

usefulness of the one-dimensional scaling (Linacre & Wright, 1994). Although it is not so subtle and sophisticate to the clinical practice, but has been frequently and consistently acceptable for detecting scale unidimensionality in literature.

In addition, a great deal of work has been devoted to the probabilistic modelling of Likert-type responses in the past 50 years (Noel & Dauvier, 2007). However, there are so many patient's clinical data that are not limited to the categorically ordered data. How we can enjoy Wright map and KIDMAP in health assessment using continuous responses is an interesting topic. Samejima (1973) developed a unidimensional latent trait model for continuous responses, but it did not aim at "specifically objective" comparisons of persons and items, which is a key and unique feature of Rasch models (Rasch, 1960). The percentages with continuous Rasch models was proposed (Linacre, 2001; Müller, 1987). The author-made computer module under Rasch model's perspective can deal with missing data and be available for continuous responses. Interested readers are welcome to request (or download) the module for practice and use (Chien, 2016). We think that (1) the module can help cancer treatment teams improve their adherence rates and (2) hospitals should report Wright map and KIDMAP together for continuous CRC quality-of-care improvement.

In conclusion, the Rasch model is suitable and appropriate for addressing this type of binary (i.e., 1 and 0) and/or missing data, and easily used in Microsoft excel. We hope that this article contributes to ensuring that hospitals adhere to the quality-of-care treatment guidelines for CRC patients.

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DISCLOSURE

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

All authors have read and approved the final manuscript. Chien developed the study concept and design. Chien and Uen analysed and interpreted the data. Chien, Wen and Chang drafted the manuscript and all authors have provided critical revisions for important intellectual content. The study was supervised by Uen.

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