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PHYSIOLOGY & REHABILITATION | RESEARCH ARTICLE

Revisiting the psychometric properties of a revised Danish version of the McGill ingestive skills assessment

Tina Hansen^{1*} and Dorte Melgaard Kristiansen²

Abstract: *Background:* During a longstanding validation process of the Danish version of the McGill Ingestive Skills Assessment (MISA2-DK) for measuring mealtime performance in dysphagic clients, extensive revisions have been undertaken. Therefore, this study aimed to determine the psychometric properties of this revised version. *Methods:* In a cross-sectional study, 328 adults referred to occupational therapy for swallowing evaluation were included. MISA2-DK with 36 items distributed into four subscales (positioning for meals, self-feeding skills, liquid ingestion, and solid ingestion) was administered as observation during a meal. Statistical analysis included item analysis by the Rasch model and exploratory factor analysis (EFA). *Results:* The initial analysis of MISA2-DK presented misfit to the Rasch model, which was resolved by grouping items within subscales into testlets to adjust for local item dependency. However, when testing the items within each subscale, the subscale structure was not supported. The EFA and further item analysis by the Rasch model suggested a different distribution of items—namely, anticipation, bolus preparation, bolus propulsion, and airway protection. *Conclusion:* The total MISA2-DK score might provide a unidimensional measure of mealtime performance. However, for detailed information of qualitative aspects of dysphagic clients' mealtime performance, the four EFA-derived subscale domains are recommended.

ABOUT THE AUTHORS

Dr Tina Hansen is Senior lecturer at the Division of Physical and Occupational Therapy at the Metropolitan University College in Denmark. Dr Hansen's work is focused on the optimization of activity-based measurement tools for rehabilitation planning as well as motor learning principles and activity-based interventions targeting the swallowing function among adults suffering from dysphagia.

Dorte Melgaard Kristiansen is a PhD student at the Aalborg University in Denmark, and has an interest in dysphagia and its implications among frail elders with community acquired pneumonia. The current article supports the continuing collaboration between the authors, which aims to improve the application of evidence-based and activity-based principles in dysphagia management.

PUBLIC INTEREST STATEMENT

Mealtimes are important events in everyday life for everyone, as they are linked to our physical health and are associated with social interactions, fun and emotional support. Adults with disabilities can experience swallowing difficulties and choking during meals with potentially harmful health and psychosocial consequences, which decreases quality of life. To provide proper mealtime support, health care professionals employ mealtime observations as a part of the investigation procedures for the swallowing function. A longstanding research process has resulted in a robust assessment procedure of mealtime performance related to mealtime positioning and self-feeding skills as well as functions related to taking in and manipulating solids and liquids through the mouth and throat into the body. By using this assessment procedure, occupational therapists could validly document impaired skills during meals, which can provide important information for choosing relevant strategies enabling safe and enjoyable meals.

Subjects: SPC/Reliability/Quality Control; Stochastic Models & Processes; Statistical Theory & Methods; Rehabilitation Medicine; Occupational Therapy; Rehabilitation Medicine

Keywords: deglutition disorders; meals; observation; assessment; occupational performance; psychometrics; Rasch model; factor analysis

1. Introduction

Swallowing disorders (dysphagia) in adults are a secondary consequence of several underlying pathologies that affect the ability to safely and efficiently eat and drink during meals (Roden & Altman, 2013; Shaker, Easterling, Belafsky, & Postma, 2012). Dysphagia is associated with high morbidity and mortality due to increased risk of aspiration pneumonia and malnutrition (Altman, Yu, & Schaefer, 2010; Roden & Altman, 2013) and negatively influences quality of life for the sufferers and their families (Cichero & Clavé, 2012). Feeding, eating and drinking, essential for adequate nutrition and hydration, are forms of social interaction involved in many occupations of everyday life (Clark, Avery-Smith, Wold, Anthony, & Holm, 2007). Individuals with dysphagia report social and psychological problems such as anxiety, shame, loss of control and lack of enjoyment while eating and drinking (Martino, Beaton, & Diamant, 2009). This may lead to social isolation and the avoidance of participation in meal-related activities (Klinke, Wilson, Hafsteinsdóttir, & Jónsdóttir, 2013). Accordingly, the affected individual must cope with the life-threatening and social consequences of dysphagia (Cichero & Clavé, 2012). Therefore, comprehensive assessment, which includes systematic observation of actual mealtime performance, is highly recommended (Danish Health Authority, 2015; Klinke et al., 2013; Scottish Intercollegiate Guidelines Network [SIGN], 2010; Shaker et al., 2012).

On the multidisciplinary dysphagia rehabilitation team, occupational therapists (OTs) provide information on the specific performance components involved in self-feeding, eating/drinking and swallowing during meals (Clark et al., 2007; Hansen, Kjaersgaard, & Faber, 2011). Such systematic observation of mealtime performance should preferably be undertaken using rating-scale-based measurements for documentation (de Vet, Terwee, Mokkink, & Knol, 2011). A systematic review (Hansen, Kjaersgaard, et al., 2011) suggests that the Canadian McGill Ingestive Skills Assessment (MISA) (Lambert, Gisel, Wood-Dauphine, Groher, & Abrahamowicz, 2006) provides OTs with adequate valid and reliable observation-based measures of actual mealtime performance.

Observed mealtime performance is a complex and integrated neuromuscular process of the following: *anticipation* with somatosensory, cognitive, pre-oral motor and psychosocial factors engendered by the meal; *bolus preparation* with bolus manipulation and formation in the mouth; *bolus propulsion* through the oral cavity, pharynx and oesophagus into the stomach; and *airway protection* (Clark et al., 2007; Leopold & Kagel, 1997). In MISA, this process is expressed as 43 ingestive skill items to be rated on a three-point ordinal scale, which are summed into five subscale scores related to *positioning*, *self-feeding skills*, *liquid ingestion*, *solid ingestion* and *texture management* as well as into a total score (Lambert et al., 2006). As such, both multidimensional measures and a single unidimensional measure of the latent construct of mealtime performance are provided (Christensen, Kreiner, & Mesbah, 2013).

MISA was translated into a Danish version (MISA-DK) (Hansen, Lambert, & Faber, 2011) and has been validated using classical test theory (Hansen, Lambert, & Faber, 2012a, 2012b). The Danish validation process added item analysis by the Rasch model (Hansen, 2014; Hansen et al., 2012b) within the conventions of modern item-response theory (Christensen et al., 2013; de Vet et al., 2011). The Rasch methodology involves statistical analysis for investigating whether a set of rating scale data satisfies the assumptions of the model, which is based on principles of fundamental measurement (Christensen et al., 2013; Tennant & Conaghan, 2007). If ordinal data in a rating scale fit the assumptions in the Rasch model, transformation into an interval scale is permitted, and the summed scores are regarded as specific objective and sufficient (Christensen et al., 2013). That is, invariant comparisons of items and persons can be made in terms of a constant unit, and all available

information is in the person's or the item's total score (Christensen et al., 2013). Such features make an outcome measure very useful in clinical practice and research trials (de Vet et al., 2011).

The added item analyses by the Rasch model showed that MISA-DK did not satisfy the principles of fundamental measurement (Hansen, 2014; Hansen et al., 2012b). Accordingly, MISA-DK and MISA have been revised (Canadian Occupational Therapy Association [CAOT], 2015; Hansen, 2014) and thus require a new large-scale validation process (Christensen et al., 2013; de Vet et al., 2011). Therefore, the aim of this study was to revisit the psychometric properties of MISA2-DK to determine whether the MISA2-DK total and subscale scores satisfy the principle of fundamental measurements. Since the exact number of dimensions and the factor structure of the original MISA have never been established (Lambert et al., 2006), this study also addressed whether the MISA2-DK items should be distributed into alternative subscales.

2. Method

2.1. Design and setting

The study used a cross-sectional design and involved OT departments at four regional hospitals and three community-based rehabilitation (CBR) units in Denmark (ClinicalTrials.gov, identifier No: NCT02328196).

2.2. Participants

Adults ≥ 18 years referred to an OT for swallowing evaluation because of known or suspected dysphagia of neurogenic or peripheral mechanical origin (Shaker et al., 2012) were included. All participants provided written informed consent that their data were used for the study. Participants with severe cognitive impairment, poorly controlled psychosis or known contraindications to ingest any liquids and foods were excluded. The study was approved by the Institutional Review Board at the Metropolitan University College in Copenhagen, Denmark and by the Danish Data Protection Authority (Reg. No: 2014-41-3230). According to Danish legislation, the study did not need approval by the local ethical committee in the Capital Region (Reg. No: H-2-2014-044).

2.3. Measurement

MISA2-DK consists of 36 ingestive skill items distributed into four subscales: positioning for meals (four items); self-feeding skills (seven items); liquid ingestion (11 items) and solid ingestion (14 items). All items are scored on a three-point ordinal scale (1 = absent ingestive skill; 2 = insufficient ingestive skill performance; 3 = adequate ingestive skill performance), which are summated into subscale scores and a total score. This format is a result of the revisions that included clarifications of five items, development of three new items and replication of three items from the solid ingestion subscale to the liquid ingestion subscale. The texture management items from the original version are regarded as single items not to be summarised. Instead, these items reflect the test-meal of four liquid texture categories (thin, mildly thick, moderately thick, and extremely thick) and four main solid texture categories (regular, soft, minced and moist, and pureed). Based on the assigned scores to the 36 ingestive skill items, the OT judges the participant's ability to efficiently and safely ingestion of the textures (CAOT, 2015; Hansen, 2014).

2.4. Procedure

MISA2-DK was part of the initial routine assessment procedures for dysphagia at the included sites. Specially trained OTs (Hansen, Madsen, & Sørensen, 2016) administered the MISA2-DK to the participants for observation during a test meal at breakfast or lunchtime from September 2014 to June 2015. For inpatient participants, the assessments occurred at the hospital ward. For participants in CBR, the assessment occurred at the CBR unit or in the home environment.

2.5. Data analysis

Descriptive statistics were conducted using IBM Statistics SPSS® version 22 for Windows (SPSS Inc., Chicago, IL) to describe the characteristics of the sample and perform missing values analysis of the

score records on the MISA2-DK items. An acceptable percentage of missing values was less than 15% per item (de Vet et al., 2011).

The psychometric properties were analysed in three stages. The first stage used item analysis by the Rasch model to test whether the MISA2-DK total scale and the proposed subscales met the model expectations. The second stage used exploratory factor analysis (EFA) to determine the dimensions underpinning MISA2-DK, and the third stage tested whether these new subscales met the assumptions in the Rasch model.

Item analysis by the Rasch model was conducted using RUMM2030 (Andrich, Lyne, Sheridan, & Luo, 2010), which integrates a pairwise conditional maximum likelihood algorithm in the estimation of item and person parameters that are placed on the same logit-scale centred by a mean item location of zero. Positive values reflect difficult items and high ability levels, and negative values reflect easy items and low ability levels (Andrich & Luo, 2002; Christensen et al., 2013). A significant likelihood ratio test ($p < 0.001$) indicated adoption of the Partial Credit model that allows each item to have a unique rating scale structure (Christensen et al., 2013). Because of the specific objectivity property of the Rasch model (Christensen et al., 2013), missing values were handled without any imputation.

The analysis followed established procedures (Christensen et al., 2013; Hagquist, Bruce, & Gustavsson, 2009; Pallant & Tennant, 2007) and was initiated as follows:

The overall fit of the scale to the model was investigated by an item-trait interaction using the chi-square (χ^2) statistic. A non-significant probability value indicates that there is no substantial deviation from the model and that the scale items function hierarchically from easy to difficult in the same pattern across all ability groups (i.e. are invariant). In addition, the overall person and item fit was addressed by inspecting the mean item and person standardised fit residuals (FR), which should be close to zero with a SD of 1.4 or less (Hagquist et al., 2009; Pallant & Tennant, 2007). The unidimensionality of the scale (i.e. all items in the rating scale measure a single construct) was assessed using principal component analysis conducted on the residual correlations to identify subsets of items loading positively and negatively on the first principal component. Person estimates from these two subsets of items were compared through a series of independent *t*-tests. If less than 5% of these tests are significant or if the lower bound of an exact binomial confidence interval is below 5%, the scale can be considered unidimensional (Hagell, 2014; Smith, 2002). The Person Separation Index (PSI) and Cronbach's alpha assessed the reliability of the scale, and values of 0.7 and 0.9 indicate sufficient reliability for group and individual use (Fisher, 1992).

Next, sources of deviation from model expectations were addressed. Misfitting items and persons were identified by standardised FR values outside the range ± 2.5 and a significant χ^2 statistic (Hagquist et al., 2009; Pallant & Tennant, 2007). Misfitting items or persons were removed in a stepwise procedure to obtain an overall fit to the model. The structure of the score categories was investigated by studying the thresholds of each item. Thresholds refer to the point between two adjacent score categories where both scores are equally probable and monotonicity is expected. That is, there is a monotonic relationship between the increasing item score and increasing level of the latent construct (Andrich, de Jong, & Sheridan, 1997). Disordered thresholds were resolved by combining adjacent categories (Andrich et al., 1997). Local item independency, which means that a person's score on one item does not depend on another item's score (Christensen et al., 2013), was evaluated using the residual correlation matrix. Residual correlation values > 0.2 above the average residual correlation was taken as an indicator for local item dependency (LID) (Christensen, Makransky, & Horton, 2015). LID was adjusted by combining the dependent items to form a larger item, called a testlet (Marais & Andrich, 2008). If the pattern of the residual correlations suggests that LID were between clusters of items within subscales, the items were grouped and treated as a testlet (Andrich, 2015; Nilsson & Tennant, 2011; Reise, Morizot, & Hays, 2007). When testlets of subscale domains are added to form a total score, RUMM2030 allows the variance components of a multidimensional

construct to be separated into the common variance component (responsible for the correlation of the dimensions) and the dimension-specific variance component (Andrich, 2015). The latent estimate (i.e. mealtime performance) was the assessment associated with this common variance of the items in the testlets after having discarded the unique variance related to multidimensionality (i.e. the different aspects covered by each testlet) (Andrich, 2015). The absence of a differential item function (DIF) was also addressed. No DIF implies that a particular item's score does not differ due to exogenous factors for persons with equal ability levels (Christensen et al., 2013; Tennant & Pallant, 2007). DIF was evaluated for three age groups with similar sample sizes (32–73 years, 74–84 years, 85–108 years), sex (female, male), and setting (hospital or CBR) and was tested by conducting an analysis of variance of the standardised residuals. If there is a consistent systematic difference in the records to an item across the latent construct (i.e. uniform DIF), it was resolved by splitting the item into the number of compared groups (Tennant & Pallant, 2007).

For all final solutions, targeting was evaluated. To be acceptable, mean person locations should approximate the mean item threshold location (i.e. 0.0 logits), and item thresholds should cover approximately the same range of the logit scale as the person locations (Hagquist et al., 2009; Pallant & Tennant, 2007). All analysis was significant at the 5% level with a Bonferroni correction applied.

EFA was based on a polychoric correlation matrix for ordinal data (Holgado-Tello, Chacon-Moscoso, Barbero-Garcia, & Vila-Abad, 2010), using the FACTOR software program version 10.3.01 (Lorenzo-Seva & Ferrando, 2006). Observations with missing values were excluded. Bartlett's Test of specificity and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy tested suitability of the data for EFA (Beavers et al., 2013). The method of factor extraction was unweighted least squares (ULS) followed by oblique (direct oblimin) rotation of factors, which allow factors to be correlated. The scree plot and parallel analysis (PA) with optimal implementation guided the number of retained factors (Baglin, 2014). Items with factor loadings <0.35 were not retained. Items with significant loadings ≥ 0.35 on more than one factor were assigned to the factor with the highest loading value.

Sample size: For item analysis by the Rasch model, a sample size of more than 250 allows for accurate and stable person and item estimates (Chen et al., 2014). For EFA, the subject-to-item ratio should to be more than five (Beavers et al., 2013).

3. Results

In total, 328 participants were included. Table 1 displays the characteristics of the sample. The number of missing values was <15% for all MISA2-DK items with a mean of 0.75% (range 0–11%).

3.1. Stage 1: Analysis by the Rasch mode: the original MISA2-DK total scale and subscales

Table 2 (Analyses 1–9) displays the overall summary fit statistics, and Table 3 shows the item fit statistics of the initial analysis. As seen in Table 2 (Analysis 1), the initial analysis of all 36 MISA2-DK items showed overall model misfit. Three items and 20 participants showed misfit, three items had disordered thresholds, and DIF by setting was present for item 3 ($F(df) = 16.71(1)$, $p < 0.001$) with inpatient participants more likely to obtain a higher score. LID was identified between items within and between all four subscales (see Table 3). The best fitting solution was to use testlets to adjust LID between items within the four subscales, which provided excellent overall fit (Table 2, Analysis 2). The correlation between the testlets was high ($r = 0.80$), and 88% of the total variance was found to be common.

Table 1. Demographic characteristics (N = 328)

Hospital setting n (%)	191 (58.2)
Community-based rehabilitation n (%)	137 (41.8)
Female n (%)	168 (51.2)
Age years mean (SD)	77.7 (11.6)
<i>Primary diagnosis n (%)</i>	
Cerebrovascular diseases	103 (31.4)
Chronic obstructive pulmonary disease	38 (11.6)
Critical illness polyneuropathy	7 (2.1)
Dementia	33 (10.1)
Heart disease	21 (6.4)
Multiple sclerosis	7 (2.1)
Neoplasms	23 (7.0)
Parkinson disease	20 (6.1)
Pneumonia	33 (10.1)
Rheumatoid arthritis	3 (0.9)
Advanced age	40 (12.2)
<i>Texture management^a n (%)</i>	
Efficient swallow in all four liquid textures ^b	89 (27.1)
Safe swallow in all four liquid textures ^b	127 (38.7)
Efficient swallow in all four solid textures ^c	33 (10.1)
Safe swallow in all four solid textures ^c	104 (31.7)

^aJudged by the occupational therapists on basis of the scores of the 36 ingestive skill items in the revised Danish version of McGill Ingestive Skills Assessment (Hansen, 2014).

^bLiquid texture categories (thin, mildly thick, moderately thick, and extremely thick).

^cSolid texture categories (regular, soft, minced and moist, and pureed).

Separate analysis of the four subscales revealed that the *positioning subscale* was initially consistent with the Rasch model expectations (Table 2, Analysis 3). For the *self-feeding skills subscale*, three items showed misfit (item 5: FR = -3.3, $\chi^2(df) = 14.57(3)$, $p = 0.002$; item 6: FR = -4.5, $\chi^2(df) = 27.81(3)$, $p < 0.001$; and item 7 FR = -3.6, $\chi^2(df) = 19.67(4)$, $p < 0.001$). Disordered thresholds were seen for items 5 and 7, and LID was found between items 6 and 7 ($r = 0.32$). The best fitting solution was removal of the three misfitting items. However, the item-trait interaction remained significant and the reliability became very low (Table 3, Analyses 4 and 5). For the *liquid ingestion subscale*, it was necessary to remove two misfitting items (item 19: FR = 4.0, $\chi^2(df) = 14.57(2)$, $p < 0.001$ and item 20: FR = 2.5, $\chi^2(df) = 17.40(3)$, $p < 0.001$) and to adjust LID between items 12 and 13 ($r = 0.43$) (Table 2, Analyses 6 and 7). To improve the overall model fit for the *solid ingestion subscale*, it was necessary to remove 25 misfitting participants and one misfitting item (item 32: FR = 3.4, $\chi^2(df) = 20.04(3)$, $p < 0.001$) and to adjust LID between items 26 and 27 ($r = 0.48$) (Table 2, Analyses 8 and 9). No items displayed DIF.

3.2. Stage 2: EFA of 36 MISA2-DK items

The EFA of the 36 MISA2-DK items included 263 participants resulting in a subject-to-item ratio of seven. Bartlett's test of specificity was highly significant ($\chi^2(df) = 5,073.4$ (630), $p < 0.0001$), and the KMO measure was 0.86, which supports the factorability of the matrix. Both the scree plot and the

Table 2. Summary of the overall fit statics from the analysis of MISA2-DK by the Rasch model

Analysis number, scale (# items)	Item-person interaction		Item-trait interaction		Reliability	Unidimensionality		% extr.	
	Item FR mean (SD)	Person FR mean (SD)	$\chi^2(df)^a$	P	PSI/ α	t-test % (95%CI)			
<i>Original structure</i>									
1. Total scale, initial	(36)	-0.07 (1.43)	-0.24 (1.32)	290.87 (144)	<0.001	0.90/0.92	12.2	(9.5;14.8)	0.0
2. Total scale, testlets final	4 (36)	-0.01 (1.05)	-0.40 (0.99)	8.39 (16)	0.936	0.80/0.81	7.2	(4.6;9.9)	0.0
3. Positioning, initial/final	(4)	0.48 (0.75)	-0.19 (0.83)	9.97 (8)	0.267	0.61/0.80	0.4 ^c	-	27.5
4. Self-feeding skills, initial	(7)	-1.11 (2.80)	-0.30 (0.73)	99.30 (20)	<0.001	0.66/0.86	2.2 ^c	-	15.1
5. Self-feeding skills, final	(4)	0.44 (0.88)	-0.17 (0.75)	27.70 (8)	0.001	0.39/0.67	0.4 ^c	-	17.5
6. Liquid ingestion, initial	(11)	-0.29 (1.74)	-0.25 (0.89)	69.34 (22)	<0.001	0.74/0.80	6.7 ^c	(4.3;9.6)	6.8
7. Liquid ingestion, final	(8)	-0.01 (0.73)	-0.25 (0.91)	29.50 (16)	0.021	0.68/0.78	2.6 ^c	-	16.5
8. Solid ingestion, initial	(14)	-0.03 (1.58)	-0.28 (1.35)	94.38 (42)	<0.001	0.80/0.82	9.9	(7.4;12.3)	0.7
9. Solid ingestion, final	(12)	0.13 (0.98)	-0.20 (1.05)	52.70 (39)	0.036	0.78/0.80	7.9	(5.3;10.4)	1.8
<i>EFA-derived structure</i>									
10. Anticipation initial	(14)	-0.54 (1.73)	-0.27 (0.94)	123.85 (56)	<0.001	0.80/0.90	4.3	-	6.2
11. Anticipation final	(13)	-0.18 (0.93)	-0.18 (0.89)	65.51 (52)	0.099	0.77/NA ^b	NA ^b	-	6.2
12. Bolus formation initial	(4)	-0.50 (1.45)	-0.42 (1.02)	45.05 (8)	<0.001	0.70/0.80	1.6 ^c	-	18.5
13. Bolus formation final	(3)	-0.06 (0.82)	-0.70 (1.37)	13.77 (8)	0.003	0.51/0.72	NA ^d	-	21.4
14. Bolus manipulation initial	(4)	-0.36 (2.72)	-0.53 (0.80)	26.11 (8)	0.001	0.57/0.75	2.4 ^c	-	22.6
15. Bolus manipulation final	(3)	-0.14 (0.53)	-0.31 (0.63)	17.88 (3)	<0.001	0.29/0.63	NA ^d	-	23.2
16. Bolus preparation initial	(8)	-0.19 (1.17)	-0.44 (1.21)	36.56 (24)	0.048	0.72/0.79	9.1 ^c	(6.6;11.5)	7.4
17. Bolus preparation final	(7)	-0.07 (1.05)	-0.41 (1.11)	22.45 (21)	0.374	0.70/0.74	7.8 ^c	(5.0;10.3)	7.5
18. Bolus propulsion initial	(7)	-0.32 (1.25)	-0.38 (1.07)	31.80 (21)	0.061	0.73/0.81	0.8 ^c	-	13.1
19. Bolus propulsion final	(8)	-0.17 (1.05)	-0.35 (1.03)	31.31 (24)	0.145	0.75/NA ^g	NA ^b	-	13.1
20. Airway protection initial/final	(6)	-0.07 (1.17)	-0.23 (0.95)	26.10 (18)	0.098	0.71/0.83	2.0 ^c	-	13.86
21. Testlets EFA subscales	4 (35)	0.24 (1.63)	-0.26 (0.86)	27.01 (12)	0.008	0.71/0.70	3.9	-	0.0
Optimal fit		0 (<1.40)	0 (<1.40)		>0.05 ^e	>0.70	<5%	LCI <5%	

Abbreviations: MISA2-DK: Revised Danish version of McGill Ingestive Skills Assessment; FR: Fit residual; χ^2 : Chi-square; SD: Standard deviation; *df*: Degrees of freedom; PSI: Person Separation Index; α : Cronbach's alpha; CI: Confidence interval; LCI: Lower bound of the confidence interval; extr: Extreme scores; NA: Not applicable.

^aIn RUMM2030, the persons are distributed into approximately equal ability groups of around 50 in each. During all analyses, this was checked and adapted continuously.

^bNA when items are split by DIF.

^ct-test might be biased because of too few thresholds in each set. Optimally, this procedure requires that at least 12 category thresholds are present in each of the subtests being compared (Hagell, 2014).

^dBonferroni adjusted with a significance level of 0.05.

^eBonferroni adjusted.

Table 3. Item level fit statistics from the initial analyses of MISA2-DK by the Rasch model

	LOC	SE	FR	$\chi^2(df)$	p	DIF	DT	RC
<i>Positioning</i>								
1. Maintains symmetry of posture	0.28	0.09	-0.16	1.54 (4)	0.820			2,3,4
2. Maintains adequate head position for feeding	-0.39	0.10	-1.56	7.58 (4)	0.108			1,2,3
3. Maintains adequate pelvis position ^a	0.41	0.09	-0.18	1.72 (4)	0.786	Setting		1,2,4
4. Maintains postural stability in the trunk	0.85	0.08	-0.74	3.51 (4)	0.477			1,3,6,7,11
<i>Self-feeding skills</i>								
5. Selects appropriate utensil for food item ^a	0.31	0.08	1.18	9.30 (4)	0.054		x	6,7,8
6. Grasps utensil/food functionally and brings it to the mouth	0.21	0.09	-2.19	9.83 (4)	0.043		x	5,7,8,11
7. Grasps cup/glass functionally and brings it to the mouth	0.00	0.09	-1.98	12.26 (4)	0.016		x	4,5,6,8,12
8. Takes appropriately-sized mouthfuls	0.64	0.08	-1.44	4.82 (4)	0.306			5,6,7,9
9. Demonstrates good judgment	-0.07	0.10	-1.09	3.87 (4)	0.425			8,10
10. Focus and maintains attention on the meal ^a	-0.45	0.10	2.03	17.00 (4)	0.002			11
11. Completes the meal without fatigue	0.26	0.09	-0.11	4.95 (4)	0.293			4,6,10
<i>Liquid ingestion</i>								
12. Seals lips on cup/glass ^a	-0.86	0.12	-2.32	16.46 (4)	0.002			7,13,14,23
13. Prevents leakage of liquid from cup/glass while drinking ^a	-0.83	0.11	-2.74	14.72 (4)	0.005			12,14,16,25
14. Prevents leakage of liquid from mouth before swallow	-1.21	0.12	-2.22	14.60 (4)	0.006			12,13,25
15. Propels liquid-bolus backwards in the mouth ^b	-1.72	0.12	-1.75	8.41 (4)	0.078			16,17,18,29,30
16. Drinks liquids with a standard straw	-0.39	0.11	-1.65	10.80 (4)	0.029			13
17. Swallows without extra effort ^c	-0.19	0.11	0.45	4.33 (4)	0.363			15,18,30
18. Swallows only once or twice per mouthful ^c	-0.96	0.12	0.06	2.73 (4)	0.604			15,17,31
19. Maintains respiratory pattern while drinking ^c	0.15	0.09	3.53	33.50 (4)	0.000			32
20. Drinks with a sequence of sips	1.30	0.09	2.27	8.69 (4)	0.069			
21. Demonstrates same voice quality after drinking	0.67	0.09	1.75	7.90(4)	0.095			22,35,36
22. Demonstrates clear airway after liquids	0.90	0.09	-1.01	6.88 (4)	0.143			21,35,36
<i>Solid ingestion</i>								
23. Close upper lip on utensil	-0.31	0.10	0.52	4.01 (4)	0.405			12
24. Bites off foods with the teeth ^b	0.28	0.09	0.78	6.18 (4)	0.186			26,27,28
25. Prevents the loss of food from the mouth before swallowing	-0.90	0.11	1.12	0.91 (4)	0.923			13,14,33,34
26. Positions bolus when chewing	0.15	0.10	-1.73	7.15 (4)	0.128			24,27,28
27. Uses functional chewing pattern	-0.43	0.11	-2.01	14.40 (4)	0.006			24,28
28. Chewing appropriate to food item	0.31	0.11	-0.11	1.00 (4)	0.910			24,26,27
29. Propels solid-bolus backwards in the mouth ^b	-0.14	0.12	-1.52	15.38 (4)	0.004			15,30,31
30. Swallows without extra effort	0.00	0.11	0.38	4.29 (4)	0.369			15,17,29,31
31. Swallows only once or twice per mouthful	-0.01	0.10	1.56	6.18 (4)	0.186			18,30
32. Maintains respiratory pattern while eating	0.22	0.09	3.00	29.23 (4)	0.000			19,36

(Continued)

Table 3. (Continued)

	LOC	SE	FR	$\chi^2(df)$	p	DIF	DT	RC
33. Has no residues in mouth after swallow	0.15	0.11	1.26	7.78 (4)	0.100			25,34
34. Location of food remaining in the mouth after swallow	0.63	0.10	1.21	8.84 (4)	0.065			25
35. Demonstrate same voice quality after eating	0.34	0.09	1.14	15.32 (4)	0.004			21,22,36
36. Demonstrates clear airway after solids	0.82	0.09	0.91	8.57 (4)	0.073			21,22,32,35

Abbreviations: MISA2-DK: Revised Danish version of McGill Ingestive Skills Assessment; Loc: Location; SE: Standard error; FR: Fit residual item (bold indicates misfitting residual $\geq \pm 2.5$); DIF: Differential item function; DT: Disordered thresholds; RC: Residual correlation >0.20 indicating local item dependency.

^aRevised item by refinement of item and/or score descriptions (Hansen, 2014).

^bNew developed item (Hansen, 2014).

^cItem replicated from the solid ingestion subscale (Hansen, 2014).

parallel analysis suggested extraction of five factors, which explained 53% of the total variance. As seen in Table 4, the Oblimin rotation of the five-latent-factor solution revealed that most of the 36 items loaded significantly on only one factor. Item 20, *Drinks with a sequence of sips*, failed to load significantly on any factors. The five-factor solution could be interpreted as representing different aspects of ingestion: *anticipation* (items 1–13 and item 23), *bolus formation* (item 24 and items 26–28), *bolus manipulation* (items 14, 25, 33 and 34), *bolus propulsion* in the oral cavity (items 15, 16, and 29) and the pharyngeal cavity (items 17, 18, 30, and 31), and *airway protection* (items 19, 21, 22, 35, 32, and 36).

3.3. Stage 3: Analysis by the Rasch model: the EFA-derived MISA2-DK subscales

Table 2 (Analyses 10–21) displays the item analysis by the Rasch model of the EFA-derived structure of MISA2-DK. The *anticipation subscale* did not fit the model. It was necessary to adjust LID between items 5, 6 and 7 (item 5/6: $r = 0.33$ and item 6/7: $r = 0.41$) and between items 12 and 13 ($r = 0.44$). Furthermore, it was necessary to split two items with DIF by settings that were biased towards inpatient participants (item 2: $F(df) = 10.88(1)$, $p = 0.001$ and item 3: $F(df) = 25.12(1)$, $p < 0.001$) (Table 2, Analyses 10 and 11). The *bolus formation subscale* showed model misfit. The removal of one misfitting item (item 27: $FR = -1.59$, $\chi^2(df) = 18.54(2)$, $p < 0.001$) increased the overall model fit for items, but decreased the PSI markedly (Table 2, Analysis 12 and 13). The *bolus manipulation subscale* showed misfit to the model. Removal of one misfitting item (item 33: $FR = -2.88$, $\chi^2(df) = 3.55(2)$, $p = 0.169$) improved the fit residual SD for items. However, the χ^2 -statistic was highly significant ($p < 0.001$), and the reliability was too low (Table 2, Analyses 14 and 15). Given the misfit of these two subscales, and since their items relate to bolus preparation in the mouth, they were combined. This *bolus preparation subscale* showed slight deviations from the Rasch model, which improved after adjusting LID between items 26 and 27 ($r = 0.36$) (Table 2, Analyses 16 and 17). The *bolus propulsion subscale* showed adequate fit to the model. This improved after splitting item 29, which displayed DIF by sex that were biased towards the male sex ($F(df) = 13.44(1)$, $p < 0.001$) (Table 2, Analyses 18 and 19). The *airway protection subscale* showed adequate overall fit statistics (Table 2, Analysis 20). Analysis using testlets of the four subscales *anticipation*, *bolus preparation*, *bolus propulsion* and *airway protection* resulted in approximately good model fit (Table 2, Analysis 21). The correlation between the testlets was moderate ($r = 0.65$) and 81% of the total variance was found to be common.

For all final analyses in stages 1 and 3, targeting was suboptimal (Table 5).

Table 4. Pattern matrix of a five-factor solution from ULS with oblimin rotation (N = 263)

	1	2	3	4	5
<i>Positioning</i>					
1. Maintain symmetry of posture	0.54				
2. Maintain adequate head position for feeding	0.46				
3. Maintain adequate pelvis position	0.45				
4. Maintains postural stability in the trunk	0.65				
<i>Self-feeding skills</i>					
5. Selects appropriate utensil for food item	0.80				
6. Grasps utensil/food-item functionally and brings it to the mouth	0.88				
7. Grasps cup/glass functionally and brings it to the mouth	0.90				
8. Takes appropriately-sized mouthfuls	0.51				
9. Demonstrates good judgment	0.35				
10. Focus and maintains attention on the meal	0.39				
11. Completes the meal without fatigue	0.42				
<i>Liquid ingestion</i>					
12. Seals lips on cup/glass	0.70				
13. Prevents leakage of liquid from cup/glass while drinking	0.53				
14. Prevents leakage of liquid from mouth before swallow			0.35		
15. Propels liquid-bolus backwards in the mouth				0.75	
16. Drinks liquids with a standard straw	0.38			0.43	
17. Swallows without extra effort				0.72	
18. Swallows only once or twice per mouthful				0.63	
19. Maintains respiratory pattern while drinking					0.37
20. Drinks with a sequence of sips	-	-	-	-	-
21. Demonstrates same voice quality after drinking					0.65
22. Demonstrates clear airway after liquids					0.70
<i>Solid ingestion</i>					
23. Close upper lip on utensil	0.35				
24. Bites off foods with the teeth		0.54			
25. Prevents the loss of food from the mouth before swallowing			0.43		
26. Positions bolus when chewing		0.78			
27. Uses functional chewing pattern		0.82			
28. Chews appropriate to food item		0.62			
29. Propels solid-bolus backwards in the mouth				0.45	
30. Swallows without extra effort				0.60	
31. Swallows only once or twice per mouthful				0.41	
32. Maintains respiratory pattern while eating					0.45
33. Has no residues in mouth after swallow			0.83		
34. Location of food remaining in the mouth after swallow			0.89		
35. Demonstrate same voice quality after eating					0.73
36. Demonstrates clear airway after solids					0.78

Abbreviations: ULS: Unweighted least squares.

Note: For ease of interpretation, only significant factor loadings ≥ 0.35 are displayed.

Table 5. Targeting of the original and EFA-derived MISA2-DK subscales and total scale

	Items mean (SD)	Item threshold distribution	Persons mean (SD)	Person location distribution
<i>Stage 1</i>				
Positioning final	0.0 (0.76)	-2.80; 1.61	0.96 (1.71)	-3.49; 2.99
Self-feeding skills final	0.0 (0.58)	-1.51; 1.15	0.99 (1.22)	-2.78; 2.66
Liquid ingestion final	0.0 (0.94)	-4.00; 2.51	1.68 (1.42)	-3.42; 4.01
Solid ingestion final	0.0 (0.50)	-2.62; 1.96	1.06 (1.15)	-3.57; 4.28
Testlets: original subscales	0.0 (0.11)	-1.12; 1.41	0.49 (0.52)	-2.56; 2.73
<i>Stage 3</i>				
Anticipation final	0.0 (0.56)	-2.25; 2.06	1.11 (1.25)	-3.77; 3.75
Bolus preparation final	0.0 (0.84)	-2.60; 2.44	1.31 (1.37)	-4.17; 4.11
Bolus propulsion final	0.0 (1.10)	-5.87; 3.85	2.01 (1.83)	-7.74; 4.98
Airway protection final	0.0 (0.46)	-1.56; 1.71	0.82 (1.59)	-3.25; 3.33
Testlets: EFA derived subscales	0.0 (0.12)	-1.62; 0.96	0.39 (0.38)	-0.78; 1.47

Abbreviations: MISA2-DK: Revised Danish version of McGill Ingestive Skills Assessment; SD: Standard deviation.

4. Discussion

As a part of the ongoing process of scale validation, this study revisited the psychometric properties of MISA2-DK. The number of missing values was acceptable (de Vet et al., 2011), and the item analysis by the Rasch model in stage 1 supported the psychometric properties of a total score using testlets of the original four subscales as previously published (Hansen, 2014). For the four subscale sum scores, only the positioning subscale satisfied the model expectations. For the remaining three subscales, it was necessary to remove misfitting items, and it was possible to achieve reasonable fit only for liquid and solid ingestion. None of the new developed items in MISA2-DK showed misfit, and disordered thresholds were present for as few as three of the original items, namely items 5, 6 and 7. This is an improvement compared to Hansen et al. (2012b). However, the category ordering is not operating as intended for these items, which assess the ability to choose, grasp and bring a cup/glass or utensils to the mouth. Therefore, the content of the three items might benefit from revisions (Andrich et al., 1997).

The EFA in stage 2 indicated a factor solution that did not match the original four subscales but suggested five factors interpreted as anticipation, bolus formation, bolus manipulation, bolus propulsion, and airway protection. Item 20 (Drinks with a sequence of sips) failed to load on any factors during the EFA, and it might be speculated whether drinking with a sequence of sips is a part of normal mealtime performance. However, since the physiology of multiple swallows is different from a single swallow, it is a clinically important item (SIGN, 2010; Shaker et al., 2012) but must be regarded as a single item.

The subsequent item analysis by the Rasch model in stage 3 resulted in four subscales—anticipation, bolus preparation, bolus propulsion, and airway protection -, which obtained satisfactory model fit after adjustments of DIF and LID for some items.

The initial analysis by the Rasch model in stage 1 suggested that the main reason for model misfit for the total score was LID between items within subscales. However, LID was also present between items across subscales, which largely reflected the factor solution in the subsequent EFA in stage 2. LID can be caused by response dependency or multidimensionality (Marais & Andrich, 2008). Since the items in MISA2-DK reflect a sequence of skills necessary for successful ingestion (Clark et al., 2007; Leopold & Kagel, 1997), it is likely that response dependency might have caused the observed LID. However, response dependency inflates the reliability of a scale (Marais & Andrich, 2008). When

the items within the four original subscales as well as within the four EFA-derived subscales were grouped and treated as a testlet to adjust for the LID, the reliability decreased. This might also reflect response dependency (Marais & Andrich, 2008). Applying the testlet solution for the original four subscales resulted in a very good fit to the Rasch model and with 88% of the total non-error variance as common. This supports MISA2-DK's ability to summarise the participants' ingestive skill ability profiles by a single measure (Andrich, 2015). Thus, it is possible to maintain the integrity of the original MISA2-DK scale (Nilsson & Tennant, 2011). This solution was in many ways more persuasive than the testlet solution for the EFA-derived subscales, which obtained less satisfactory overall fit to the Rasch model. This suggests that the total score based on the original four subscales might better reflect the common underlying construct of mealtime performance. A total score offers advantages in clinical identification of clients with deficient ingestive skills and may simplify research analysis for example, on the effectiveness of dysphagia rehabilitation. However, it is possible that real gains within one or two subscale domains will be obscured within a large scale assessing overall mealtime performance. Thus, grouping items into subscales will allow detailed information of a dysphagic client's ingestion profile and detailed evaluation at more specific levels. This is particularly relevant for OTs in dysphagia rehabilitation, which typically addresses several aspects of ingestive skills (Clark et al., 2007; SIGN, 2010; Shaker et al., 2012). Accordingly, this study might suggest that the four subscales related to anticipation, bolus preparation, bolus propulsion, and airway protection, which was derived in stages 2 and 3, should be used rather than the original subscales. In fact, this structure seems to be clinically and conceptual meaningful (Clark et al., 2007; Leopold & Kagel, 1997).

During the item analysis by the Rasch model in stages 1 and 3, the test for DIF revealed that items 2 and 3, which reflect basic mobility functions (Hansen, Lambert, et al., 2011), were biased towards inpatient participants, who were more likely to obtain a higher score than participants in CBR. For the participants in CBR, approximately 84% of the MISA2-DK assessments occurred in the home environment. Therefore, environmental factors, such as inappropriate furniture, might have influenced the sitting positioning. However, this can be only speculative since the data collection did not include detailed records on the mealtime environment. DIF was also found for item 29, which reflects the strength of the tongue, and was biased towards males who were more likely to obtain a higher score than females. The reason for the DIF might be that tongue strength is significantly greater in males compared to females (Adams, Mathisen, Baines, Lazarus, & Callister, 2013). Since all DIF was uniform, it was possible to split the items into group-specific items (Tennant & Pallant, 2007).

4.1. Methodological considerations

This study has certain limitations. All analyses are based upon a single sample, and it would have been desirable to replicate the analysis by the Rasch model in stage 3 with a validation sample, making the results more robust. However, although the current sample size was sufficiently large (Beavers et al., 2013; Chen et al., 2014), it did not allow division into two samples. In addition, the sample tended to be at the ceiling of the scale. For the subscales, high percentages of extreme scores were present, and the coverage of items to persons was reduced. This indicates suboptimal targeting, which might have influenced the PSI negatively (Christensen et al., 2013). Additionally, confirmatory factor analysis to test the proposed subscale structure could have been used (de Vet et al., 2011). This was performed as a part of the analyses for this study using the Bayesian approach for ordinal data. Because of the high number of items and the presence of LID, it was not possible to draw any conclusions. Finally, since a new validation process has not been applied to the Canadian MISA2, the cross-cultural validity of MISA2-DK is not yet fully established. For this, DIF analysis of merged data from both versions is needed (Christensen et al., 2013; de Vet et al., 2011).

5. Conclusion

Revisiting the psychometric properties of MISA2-DK using item analyses by the Rasch model could support a total score used to provide a unidimensional measure of mealtime performance, thus enabling identification of clients with deficient ingestive skills in clinical practice and research studies. However, given that not all four original MISA2-DK subscales—*positioning, self-feeding skills, liquid ingestion and solid ingestion*—satisfied the requirements in the Rasch model, they cannot be

recommended to obtain detailed information and identification of qualitative aspects of mealtime performance. Rather, it is recommended to use the four EFA-derived subscales: *anticipation, bolus preparation, bolus propulsion, and airway protection*. However, further testing is required to confirm the new structure.

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Competing Interests

The authors declare no competing interest.

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