

# Psychometric Evaluation of DiSMET: A Rasch Analysis of a Patient–Provider Tool for Assessing Type 2 Diabetes Self-Management Knowledge and Behavior

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## BACKGROUND

**Type 2 diabetes mellitus (T2DM)** affects **>38 million U.S. adults** and accounts for **\$412.9B** in annual costs.

**Diabetes Self-Management Education and Support (DSMES)** improves HbA1c by 0.5–1.0%, yet **<5% of Medicare beneficiaries** access these services due to rigid curricula and tools that fail to identify individual knowledge–behavior gaps.

## WHY RASCH? THE MEASUREMENT GAP

Existing instruments (DSMQ, DKQ) rely on **Classical Test Theory (CTT)**, which suffers from sample- and item-dependence — limiting cross-population comparison.

**Rasch measurement theory** places persons and items on a common, sample-independent **interval logit scale**, enabling invariant measurement, precise targeting, and DIF detection essential for clinical decision-making.

## STUDY OBJECTIVES

To psychometrically evaluate DiSMET (55 items: 29 knowledge + 26 behavior) across the **8 DSMES core content areas** using Rasch dichotomous models, by examining:

- 1 **Item-level model–data fit (infit/outfit MNSQ)**
- 2 **Unidimensionality (PCA of residuals)**
- 3 **Local item independence**
- 4 **Item–person targeting (Wright maps)**
- 5 **Item & person separation reliability**
- 6 **Differential item functioning by gender**

## METHODS & SAMPLE

**Design:** Secondary analysis of cross-sectional online survey (Apr–May 2021).

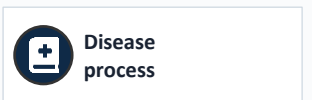
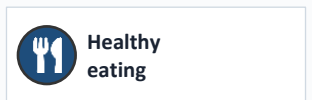
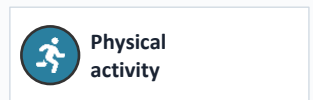
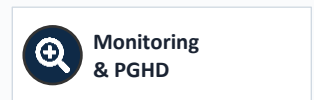
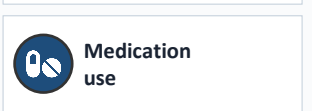
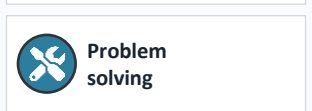
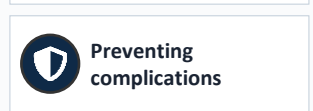
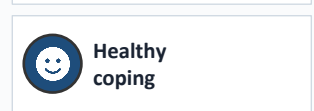
**Recruitment:** Amazon Mechanical Turk → Qualtrics.

**Eligibility:** U.S. adults ≥18 yrs with self-reported T2DM.

**Software:** WINSTEPS v5.6.0 • Rasch dichotomous model.

**Acceptable MNSQ:** 0.5–1.5 • **DIF threshold:**  $p < .001$  &  $|M-H \text{ logits}| > 0.64$ .

## 8 DSMES CORE CONTENT AREAS

|                                                                                                    |                                                                                                     |                                                                                                              |                                                                                                       |
|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
|  Disease process |  Healthy eating  |  Physical activity        |  Monitoring & PGHD |
|  Medication use  |  Problem solving |  Preventing complications |  Healthy coping    |

## SAMPLE (N = 306)

|                                        |                                                 |
|----------------------------------------|-------------------------------------------------|
| <b>306</b><br>U.S. adults<br>with T2DM | <b>88.6%</b><br>College<br>graduates            |
| <b>6.9</b><br>Mean HbA1c<br>(%, n=169) | <b>36.4</b><br>Months since<br>diagnosis (mean) |

| Demographic                       | %                 |
|-----------------------------------|-------------------|
| Male / Female / Non-binary        | 56.2 / 40.8 / 2.9 |
| Master's degree                   | 55.9              |
| Doctorate degree                  | 22.9              |
| Urban / Rural setting             | 78.4 / 21.6       |
| Knowledge / Behavior raw % (mean) | 71.7 / 68.2       |

## MODEL–DATA FIT

After review of misfitting items (MNSQ outside 0.5–1.5):

- **5 knowledge items removed** (Q3, Q9, Q11, Q23, Q37)
- **1 behavior item removed** (Q42)
- **Q30 (Outfit = 2.00) retained** on clinical-importance grounds.

**Final:** 24 knowledge + 25 behavior items demonstrated good fit.

## UNIDIMENSIONALITY & LOCAL INDEPENDENCE

| Diagnostic              | Knowledge    | Behavior     |
|-------------------------|--------------|--------------|
| Variance explained      | 24.4%        | 22.4%        |
| 1st contrast eigenvalue | 2.90         | 3.32         |
| Max residual r          | 0.29         | 0.36         |
| Threshold (< 0.7)       | ✓ <b>Met</b> | ✓ <b>Met</b> |

→ Both scales support **essential unidimensionality** and **local independence**.

## DIFFERENTIAL ITEM FUNCTIONING (GENDER)

Mantel–Haenszel DIF analysis (Male vs. Female; non-binary n=9 excluded due to small n):

✓ **Knowledge: 0 of 24 items** showed both statistically significant ( $p < .001$ ) and substantive ( $|logits| > 0.64$ ) DIF.

✓ **Behavior: 0 of 25 items** showed both statistically significant ( $p < .001$ ) and substantive DIF.

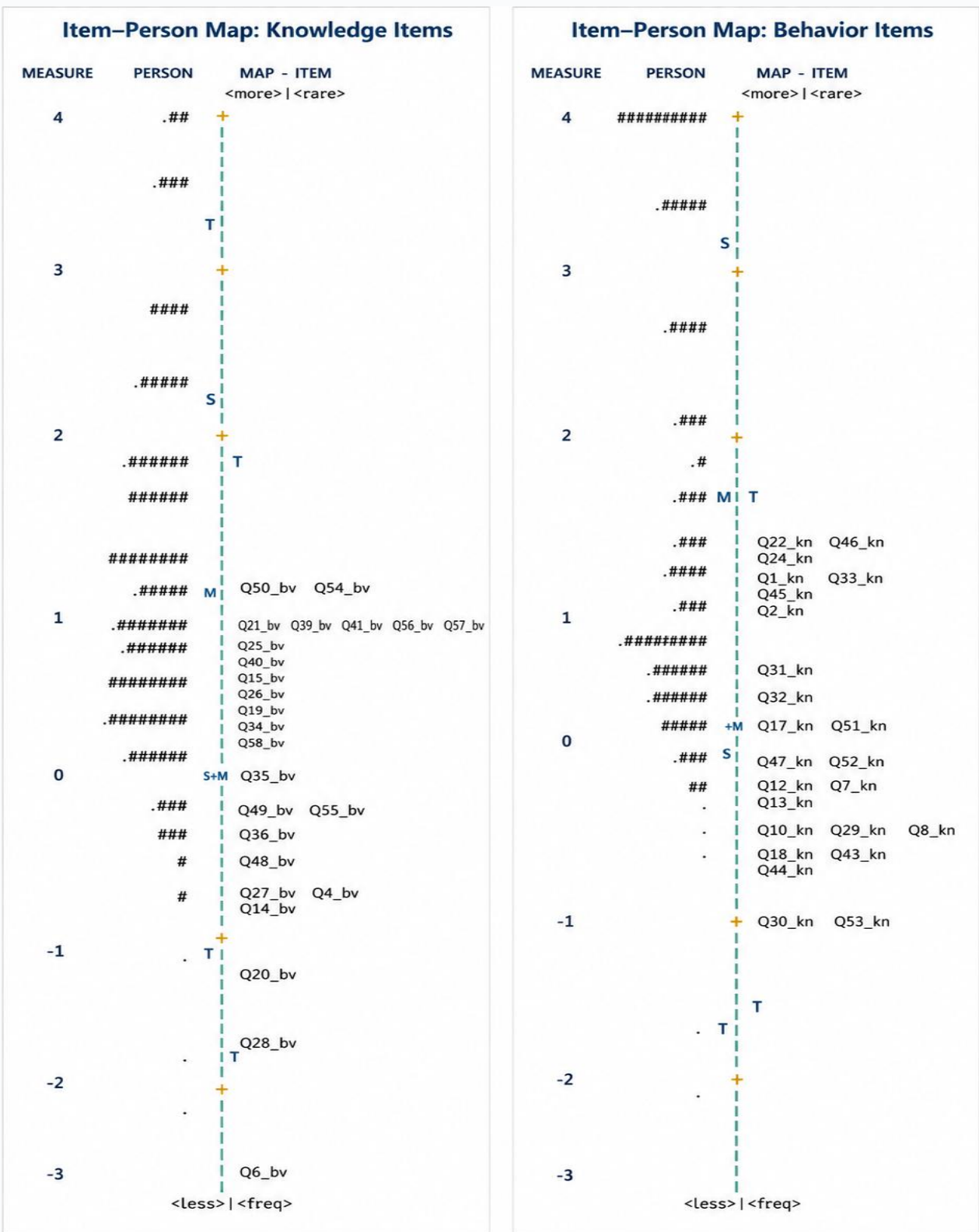
→ **Measurement invariance supported across gender groups.**

## RELIABILITY & SEPARATION

| ITEM SEPARATION RELIABILITY |             | PERSON SEPARATION RELIABILITY |             |
|-----------------------------|-------------|-------------------------------|-------------|
| Knowledge                   | Behavior    | Knowledge                     | Behavior    |
| <b>0.96</b>                 | <b>0.97</b> | <b>0.71</b>                   | <b>0.70</b> |
| EXCELLENT                   |             | MODERATE                      |             |

Item separation index: **4.85 (Knowledge)** • **6.09 (Behavior)** → *well-defined item difficulty hierarchy, expected to replicate across samples.*

## ITEM–PERSON TARGETING (WRIGHT MAP)



⚠ **Ceiling effect:** many persons above hardest items

⚠ **Ceiling effect:** persons exceed hardest items

## KEY FINDINGS

- ✓ **Item fit** — 23/24 KN & 25/25 BV in 0.5–1.5
- ✓ **Unidimensionality** — Essential support (eigenvalues 2.90 / 3.32)
- ✓ **Local independence** — Max residual  $r = 0.29 / 0.36$  (< 0.7)
- ✓ **Item separation reliability** — 0.96 / 0.97 — excellent
- ✓ **Gender DIF** — Measurement invariance maintained
- ⚠ **Person separation reliability** — 0.71 / 0.70 — moderate
- ⚠ **Item targeting** — Ceiling effect in highly-educated sample

## CLINICAL & DIABETES-CARE IMPLICATIONS

- ▶ **DiSMET supports staged, individualized DSMES** — clinicians can sequence education from easier (e.g., stress effects on glucose, Q53\_kn) to more complex topics (interpreting nutrition labels, Q22\_kn).
- ▶ **Separate knowledge & behavior scales** allow clinicians to identify whether intervention should target knowledge gaps, behavior change, or both.
- ▶ **Gender-equitable measurement** supports use across diverse patient populations.
- ▶ **Community pharmacy fit:** practical, theory-grounded tool for pharmacist-led DSMES and collaborative goal-setting.

## LIMITATIONS & FUTURE DIRECTIONS

**Limitations:** Highly-educated MTurk sample (88.6% college graduates), cross-sectional design, gender-only DIF.

**Future work:** Validate in representative T2DM populations (primary care, community pharmacy); add harder items (e.g., insulin-to-carb ratios, CGM trend interpretation, exercise-based dose adjustment) to address ceiling effects; assess DIF by age, education, race/ethnicity, and health literacy; longitudinal responsiveness to DSMES interventions.

## CONCLUSIONS

Rasch analysis confirms DiSMET as a **psychometrically sound** instrument: good item fit, essential unidimensionality, local independence, gender invariance, and excellent item separation reliability.

Moderate person separation and ceiling effects reflect **sample-specific characteristics**, not fundamental tool limitations. With expanded item difficulty range, DiSMET is positioned for clinical deployment in **community-pharmacy** and **primary-care DSMES settings**.



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## DiSMET KNOWLEDGE ITEMS (N = 24)

Item difficulty (δ) on logit scale • Range –1.10 to 1.19

| ID     | Domain            | Item (Participant agreement with the statements)                                                  | δ (logits) |
|--------|-------------------|---------------------------------------------------------------------------------------------------|------------|
| Q1_kn  | Disease process   | High blood glucose is bad for my body.                                                            | 0.99       |
| Q2_kn  | Disease process   | Diabetes can affect nerves, kidneys, and the cardiovascular system.                               | 0.76       |
| Q7_kn  | Healthy eating    | Bread, pasta, fruits, dairy products, and sugary desserts contain carbohydrates.                  | –0.34      |
| Q8_kn  | Healthy eating    | Olive oil, canola oil, and fish oil are considered healthy.                                       | –0.64      |
| Q10_kn | Healthy eating    | Recommended cooking methods for meat are roasting, boiling, and grilling.                         | –0.64      |
| Q12_kn | Healthy eating    | I should drink milk with skim or 1% fat content.                                                  | –0.34      |
| Q13_kn | Healthy eating    | Most days, half of my dinner plate should be non-starchy vegetables.                              | –0.41      |
| Q17_kn | Physical activity | Exercise reduces blood glucose, insulin needs, leg cramps, and improves mood.                     | 0.17       |
| Q18_kn | Physical activity | Physical activity usually lowers blood glucose levels.                                            | –0.83      |
| Q22_kn | Monitoring        | Self-monitoring lets you align glucose changes with your lifestyle.                               | 1.19       |
| Q24_kn | Monitoring        | A food diary helps track what and when you are eating.                                            | 1.13       |
| Q29_kn | Medication use    | Diabetes medications control blood glucose levels.                                                | –0.64      |
| Q30_kn | Medication use    | Meds boost pancreatic insulin, improve muscle insulin sensitivity, & limit hepatic sugar release. | –1.07      |
| Q31_kn | Medication use    | Insulin is administered to the body by injection.                                                 | 0.42       |
| Q32_kn | Medication use    | An insulin dose is given according to your blood glucose levels.                                  | 0.36       |
| Q33_kn | Medication use    | Insulin is injected just below the skin for slower absorption into fat.                           | 1.03       |
| Q43_kn | Complications     | Hypertension is blood pressure ≥ 140/90 mm Hg.                                                    | –0.80      |
| Q44_kn | Complications     | Low-dose aspirin can prevent heart attacks.                                                       | –0.94      |
| Q45_kn | Complications     | Diabetes + BP > 140/90 → higher CV, kidney, and eye complication risk.                            | 0.86       |
| Q46_kn | Complications     | Exercise, relaxation, and a healthier diet can lower high blood pressure.                         | 1.19       |
| Q47_kn | Complications     | 50% of people with diabetes have high blood pressure.                                             | –0.23      |
| Q51_kn | Healthy coping    | Negative emotions induce stress that can cause additional health problems.                        | 0.13       |
| Q52_kn | Healthy coping    | Best to face the disease actively and seek solutions.                                             | –0.25      |
| Q53_kn | Healthy coping    | Stress increases blood glucose levels.                                                            | –1.10      |

## DiSMET BEHAVIOR ITEMS (N = 25)

Item difficulty (δ) on logit scale • Range –2.82 to 1.26

| ID     | Domain            | Item (Participant agreement with the statements)                                     | δ (logits) |
|--------|-------------------|--------------------------------------------------------------------------------------|------------|
| Q4_bv  | Disease process   | I do a good job managing my diabetes and use regular medication regimens.            | –0.83      |
| Q6_bv  | Disease process   | I understand what is happening in my body during high or low glucose.                | –2.82      |
| Q14_bv | Healthy eating    | I use recommended food-label servings to plan my meals.                              | –0.91      |
| Q15_bv | Healthy eating    | When choosing a dinner protein, I usually eat chicken, turkey, or fish.              | 0.53       |
| Q19_bv | Physical activity | I exercise (planned/scheduled activity) generally twice a week or more.              | 0.32       |
| Q20_bv | Physical activity | I engage in everyday physical activity (walking, gardening, chores) ≥ 2 days/week.   | –1.17      |
| Q21_bv | Physical activity | If exercising, I check my blood glucose levels.                                      | 0.84       |
| Q25_bv | Monitoring        | I currently use a food diary or app to track daily eating habits.                    | 0.82       |
| Q26_bv | Monitoring        | I have experience viewing online lab/test results.                                   | 0.40       |
| Q27_bv | Monitoring        | I track my glucose levels.                                                           | –0.80      |
| Q28_bv | Monitoring        | I am confident in my ability to self-test glucose using a glucose meter.             | –1.61      |
| Q34_bv | Medication use    | I keep medications in routine — written list, pillbox, schedule.                     | 0.25       |
| Q35_bv | Medication use    | I read side effects and instructions for prescribed medications.                     | –0.07      |
| Q36_bv | Medication use    | I take my daily medications as directed by my doctor or pharmacist.                  | –0.50      |
| Q39_bv | Problem solving   | When I encounter a diabetes problem, I try to solve it and learn from it.            | 0.92       |
| Q40_bv | Problem solving   | If I get the flu and glucose rises, I monitor more, contact my provider, & research. | 0.71       |
| Q41_bv | Problem solving   | On vacation without a gym, I ask about walking trails and walk as much as possible.  | 0.92       |
| Q48_bv | Complications     | I frequently communicate with a diabetes educator or healthcare professional.        | –0.58      |
| Q49_bv | Complications     | I receive a flu shot every year.                                                     | –0.31      |
| Q50_bv | Complications     | I do not currently smoke and have never smoked.                                      | 1.26       |
| Q54_bv | Healthy coping    | When I assess diabetes' emotional impact, I generally feel positive.                 | 1.18       |
| Q55_bv | Healthy coping    | My coping = relaxation, rest, family time, and a positive attitude.                  | –0.39      |
| Q56_bv | Healthy coping    | My attitude toward diabetes treatment is committed and headstrong.                   | 0.89       |
| Q57_bv | Healthy coping    | When diagnosed, I reacted positively and optimistically.                             | 0.87       |
| Q58_bv | Healthy coping    | I become eager to seek support from professionals, family, and friends.              | 0.07       |