ABSTRACT
Objective: to analyze the latent traits of knowledge about diabetes and health literacy of adults with type 2 diabetes mellitus. Method: an exploratory, descriptive, cross-sectional, and quantitative study was conducted with 33 participants from the Metropolitan Region of Curitiba, Paraná, Brazil. Data were collected in the first quarter of 2020 using a sociodemographic and clinical questionnaire, the Spoken Knowledge in Low Literacy Patients with Diabetes questionnaire, and the Eight-Item Health Literacy Assessment Tool. Data were analyzed descriptively, using Item Response Theory, Cronbach's alpha, and Pearson's Correlation Coefficient. Results: there was a female predominance (n = 23), with a mean age of 57.0 ± 8.08 years, education of 7.72 ± 3.69 years, and family income of 3,118.18 ± 3,063.28. The latent trait with the greatest difficulty in understanding diabetes was related to the signs and symptoms of hyperglycemia and hypoglycemia. A moderate positive correlation (r = 0.4260) was found between knowledge of the disease and family income. Defining high-quality internet sources was the item with the lowest average difficulty in health literacy. Conclusion: the latent traits of the two instruments, expressed by the participants, revealed the main difficulties in maintaining disease control, supporting the development of actions to address the gaps.

Descriptors: Health Literacy; Diabetes Mellitus Type 2; Statistics as Subject; Surveys and questionnaires; Adult Health.

RESUMO
Objetivo: analisar os traços latentes do conhecimento acerca da diabetes e do letramento em saúde de adultos com diabetes mellitus tipo 2. Método: pesquisa descritiva exploratória, de recorte transversal e abordagem quantitativa, com 33 participantes da Região Metropolitana de Curitiba, Paraná, Brasil. Os dados foram coletados no primeiro trimestre de 2020, por questionário sociodemográfico e clínico, Spoken Knowledge in Low Literacy Patients with Diabetes e Eight-Item Health Literacy Assessment Tool. Analisaram-se os dados descritivamente, pela Teoria de Resposta ao Item, alfa de Cronbach e Coeficiente de Correlação de Pearson. Resultados: predominio do sexo feminino (n = 23), com média de idade de 57,0 ± 8,08 anos, escolaridade de 7,72 ± 3,69 anos e renda familiar de 3.118,18 ± 3.063,28. O traço latente com maior dificuldade do conhecimento da diabetes foi relativo aos sinais e sintomas da hiperiglicemia e hipoglicemia. Constatou-se correlação positiva moderada (r = 0,4260) entre conhecimento da doença e renda familiar. Definir as fontes seguras da Internet foi o item com a menor dificuldade média do letramento em saúde. Conclusão: os traços latentes dos dois instrumentos, expressos pelos participantes, revelou as maiores dificuldades para manter o controle da doença, permitindo o desenvolvimento de ações para as lacunas.

Descritores: Leitramento em Saúde; Diabetes Mellitus Tipo 2; Estatística como Assunto; Inquéritos e questionários; Saúde do Adulto.

RESUMEN
Objetivo: analizar los rasgos latentes del conocimiento sobre diabetes y la alfabetización en salud de adultos con diabetes mellitus tipo 2. Método: investigación descriptiva exploratoria, transversal y cuantitativa, con 33 participantes de Región Metropolitana de Curitiba, Paraná, Brasil. Los datos se recopilaron en el primer trimestre de 2020, utilizando un cuestionario sociodemográfico y clínico y los cuestionarios Spoken Knowledge in Low Literacy Patients with
**Diabetes y Eight-Item Health Literacy Assessment Tool.** Los datos fueron analizados descriptivamente utilizando la Teoría de Respuesta al Ítem, el Alfa de Cronbach y el Coeficiente de Correlación de Pearson. **Resultados:** predominio del sexo femenino (n = 23), con media de edad de 57,0 ± 8,08 años, escolaridad de 7,72 ± 3,69 años y renta de 3.118,18 ± 3.063,28. El rasgo latente con mayor dificultad fue relacionado con los signos y síntomas de hiperglucemia e hipoglucemia. Se encontró una correlación positiva moderada (r = 0,4260) entre el conocimiento de la enfermedad y la renta. Definir fuentes seguras de Internet fue el ítem con menor dificultad promedio en alfabetización en salud. **Conclusion:** los rasgos latentes de los dos instrumentos revelaron las mayores dificultades para mantener el control de la enfermedad, contribuyendo a el desarrollo de acciones.

**Descriptores:** Alfabetización en Salud; Diabetes Mellitus Tipo 2; Estadística como Asunto; Encuestas y Cuestionarios; Salud del Adulto.

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**INTRODUCTION**

The Item Response Theory (IRT) is a psychometric evaluation method to analyze the skills or performance of questionnaire respondents, by the item difficulty parameters, by the chance of getting it right by chance, and by the power of discrimination, which distinguishes the participants who have proficiency in the evaluated item from those who do not. Thus, in IRT, items/questions are evaluated individually and are called latent traits.1

The foundation of the latent trait consists of a mathematical formula related to the observed variables (test items) and hypothetical variables (interpretive ability, summarization of ideas, and distractions). Thus, the latent variable is the cause and the response, the effect, which cannot be directly evaluated since it involves the psychological characteristics of the tested participant and is identified by the Item Characteristic Curve (ICC).2 The ICC is understood as a behavioral expression of the participant's psychic process (Theta θ), being analyzed by the parameters of difficulty and discrimination, in which difficulty is associated with a probability of 50% of success.3

As in any psychometric evaluation, the total number of correct answers in the IRT is not questioned, but whether the participant understands the questions.2 The IRT is widely used in Brazil in processes related to student performance, as it proved to be the most advantageous method to obtain reliable results on the reasons for successes and failures.4 In health, the theory has been used to construct and validate instruments and occupies a prominent place in the academic and scientific environment for its innovative character.5

An integrative literature review analyzed the use of IRT in public health research, evaluating 56 studies that used it in the development of measures, validation, and reliability of constructs, calibration of items, and evaluation of psychometric adjustments, with quality of life,
the health of the elderly, and Health Literacy (HL) being the most evaluated latent traits. The authors encourage using IRT to analyze and validate new instruments to measure the latent traits of comprehensive care, health promotion, and access to health services.6

In this sense, HL is a health promotion concept related to developing cognitive and social skills to obtain, process, and use health information and services to maintain good health and prevent injuries.7 Therefore, there is a need to analyze the difficulties for Diabetes Mellitus (DM) self-management considering the latent traits related to knowledge about the disease and HL, which are influenced by educational, social, and economic factors.8

Notably, self-management's antecedents comprise the knowledge about the disease, the search for information on the health-disease process, motivation, social support, and self-efficacy resulting in DM control, improvement in quality of life and self-esteem, satisfaction, and empowerment.9 Given that DM and HL knowledge is an antecedent of self-management, we question whether the use of the IRT for the analysis of latent traits of instruments measuring DM and HL knowledge enables the identification of item discrimination and difficulties faced by participants with type 2 diabetes mellitus (DM2) to manage the disease.

**OBJECTIVE**

The study objective was to analyze the latent traits of knowledge about diabetes and the health literacy of adults with type 2 diabetes mellitus.

**METHOD**

An exploratory, descriptive, cross-sectional, and quantitative study was conducted according to the recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.10 The data collection took place in the first quarter of 2020 in a Family Health Strategy (FHS) unit in the Metropolitan Region of Curitiba, Paraná, Brazil, which had a population of 10,141 registered users and 516 subjects diagnosed with DM.

The following inclusion criteria were established: age between 18 and 65 years, diagnosis of DM2, enrollment in the local Hypertension and DM Program (Hiperdia in Portuguese), and uncontrolled glycemia (fasting glucose ≥126mg/dL or glycated hemoglobin, Hb1Ac ≥ 7%) recorded in the medical record in 2019 or 2020. Users with comorbidities that prevented communication were excluded by consulting the electronic medical record or assessing the subjects during the nursing consultation.

The participant recruitment to the convenience sample was conducted using a list provided by the local health authority, with the registration data of Hiperdia users, which helped actively search the electronic medical records of the 78 eligible individuals. The main researcher made three telephone attempts to present the study and invite the participants on different days and times. The telephone attempts took place on business days and hours and failed to reach 32 subjects due to incorrect numbers, the inexistence of the number, or the absence of an answer. Furthermore, six users refused to participate. A total of 40 volunteer participants were recruited for whom a nursing appointment was scheduled at the primary health unit or home, according to the subject's choice.
In the nursing consultation, one person refused to participate, five presented the last test results with values diverging from the parameters established for the research, and one had Alzheimer's in an advanced stage with impaired communication. The final sample consisted of 33 participants who answered the sociodemographic and clinical questionnaire, the Spoken Knowledge in Low Literacy Patients with Diabetes (SKILLD)\textsuperscript{11} questionnaire, and the Eight-Item Health Literacy Assessment Tool (HLAT-8).

The sociodemographic and clinical questionnaire consisted of the self-declared variables of gender, age, years of education, family income, and time since the diagnosis of the disease, in addition to information on fasting blood glucose and Hb1Ac obtained from the medical records. The research group validated the questionnaire on adult health to which the authors belong.

The SKILLD questionnaire (Brazilian version) was used to verify the knowledge of DM, which includes 10 questions with scores from zero to 100%. The instrument was validated in a sample of 129 elderly people with DM2, obtaining a reliability of 0.75 using Cronbach's alpha.\textsuperscript{11} The HLAT-8 (Brazilian version) consists of eight questions, with scores ranging from zero to 37, and aims to measure the levels of HL. A prior validation was carried out in a sample of 472 young university students and obtained a Cronbach's alpha of 0.83.\textsuperscript{12}

Data were entered into Microsoft Excel 365\textsuperscript{®} spreadsheets and double-checked. The statistical analysis was performed using an extension of the program linked to the eIRT add-in (https://libirt.psychometricon.net/). Sociodemographic and clinical variables were descriptively analyzed by central tendency measures (mean and standard deviation, SD) and simple and relative frequencies (number, n, percentage, %). Pearson's correlation coefficient was used to verify the relationship between fasting blood glucose and family income. Fasting blood glucose and Hb1Ac information described in the medical records of 30 and 26 participants, respectively, were obtained.

The SKILLD was analyzed using latent variables and, subsequently, by applying Pearson's correlation coefficient to test the correlation between knowledge about the disease and age and between knowledge about the disease and family income. The HLAT-8 results were analyzed for mean difficulty, SD, and item discrimination. Cronbach's alpha was applied to test the reliability of the SKILLD and HLAT-8 instruments for the adult population.

This research respected the Resolution n° 466/2012 of the Brazilian Health Council and was approved by the Research Ethics Committee of a Public University in the South of Brazil, under opinion n° 3,752,041.

### RESULTS

The profile of the participants was predominantly composed of women, 23 (69.7%), with a mean age of 57.0 ± 8.08 years and 7.72 ± 3.69 years of education. The family income ranged from R$ 180 to R$ 13,000 (3,118.18 ± 3,063.28). Concerning the clinical variables, the DM diagnosis time ranged from one to 22 years (11.3 ± 6.42), the mean fasting glucose was 197.1 ± 93.8, and the mean Hb1Ac was 9.16 ± 2.38.
A weak correlation was obtained between family income and fasting blood glucose of the 30 participants ($r = 0.1946$), indicating that the higher the income, the greater the probability of having low fasting blood glucose (Graph 1).

Graph 1. Correlation between fasting blood glucose and family income by the IRT. Metropolitan Region of Curitiba, PR, Brazil, 2020.

Regarding the values of the latent variables of the SKILLD, it was observed that the main difficulties faced by the participants involved the understanding of the signs and symptoms of hyperglycemia (question 1) and hypoglycemia (question 2), the normal value of the HbA1c test (question 8) and the frequency with which a person with DM should examine his or her feet (question 4). In contrast, questions three and seven were the items best understood by the participants. The lower the value of the latent variable, the greater the difficulty in getting the right answer to a specific item (Table 1).

Table 1. Values of the SKILLD latent variables. Metropolitan Region of Curitiba, PR, Brazil, 2020.

<table>
<thead>
<tr>
<th>Questions from the Spoken Knowledge in Low Literacy Diabetes</th>
<th>Latent Variable*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) What are the signs and symptoms of high blood glucose?</td>
<td>0.152</td>
</tr>
<tr>
<td>2) What are the signs and symptoms of low blood glucose?</td>
<td>0.333</td>
</tr>
<tr>
<td>8) What is a normal HbA1c?</td>
<td>0.364</td>
</tr>
<tr>
<td>4) How often should a person with diabetes check his or her feet?</td>
<td>0.394</td>
</tr>
<tr>
<td>10) What are some long-term complications of uncontrolled diabetes?</td>
<td>0.485</td>
</tr>
<tr>
<td>9) How many times per week should someone with diabetes exercise, and for how long?</td>
<td>0.545</td>
</tr>
<tr>
<td>5) Why are foot exams important for someone with diabetes?</td>
<td>0.606</td>
</tr>
</tbody>
</table>

*Item response theory.
By correlating the SKILLD scores with age, the value of $r = -0.03$ was obtained, indicating no relationship between age and difficulty in responding to the instrument’s items (Graph 2).

Graph 2. Correlation between SKILLD scores and age by the IRT. Metropolitan Region of Curitiba, PR, Brazil, 2020.

A moderate positive correlation ($r = 0.4260$) was obtained between SKILLD scores and family income, indicating that the higher the income, the greater the knowledge about DM (Graph 3).

Graph 3. Correlation between SKILLD scores and family income by the IRT. Metropolitan Region of Curitiba, PR, Brazil, 2020.

Regarding the HLAT-8 analysis, the questions with the greatest difficulty were obtaining health information on the Internet and determining which sources are good quality (question 8) ($1.515 \pm 1.459$), and understanding the instruction leaflets for the medication (question 1) ($1.636 \pm 1.630$). Questions three, four, and six (discrimination: $-0.048$, $-0.048$, and $-0.130$) had values lower than zero, indicating that these items do not have the power to distinguish the participants’
skill levels. The average difficulty, SD, and HLAT-8 discrimination values are presented in Table 2.

Table 2. Distribution of HLAT-8 item values. Metropolitan Region of Curitiba, PR, Brazil, 2020.

<table>
<thead>
<tr>
<th>Eight-Item Health Literacy Assessment Tool</th>
<th>Average difficulty</th>
<th>SD</th>
<th>Discrimination*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) How well do you understand instruction leaflets for medication?</td>
<td>1.636</td>
<td>1.630</td>
<td>0.511</td>
</tr>
<tr>
<td>2) How well do you understand information brochures on health issues?</td>
<td>2.152</td>
<td>1.777</td>
<td>0.305</td>
</tr>
<tr>
<td>3) When I have questions about diseases or complaints, I know where I can find information on these issues.</td>
<td>2.727</td>
<td>0.708</td>
<td>-0.048</td>
</tr>
<tr>
<td>4) When I want to do something for my health without being sick, I know where I can find information on these issues.</td>
<td>2.152</td>
<td>1.104</td>
<td>-0.048</td>
</tr>
<tr>
<td>5) How often were you able to help your family members or a friend if they had questions concerning health issues?</td>
<td>3.667</td>
<td>1.589</td>
<td>0.338</td>
</tr>
<tr>
<td>6) When you came up with questions concerning health issues, how often were you able to get information and advice from others (family and friends)?</td>
<td>3.303</td>
<td>1.766</td>
<td>-0.130</td>
</tr>
<tr>
<td>7) How well are you doing in choosing the advices and offers that fit you the most?</td>
<td>3.576</td>
<td>0.740</td>
<td>0.375</td>
</tr>
<tr>
<td>8) Regarding information on health on the Internet, I'm able to determine which sources are of high and which are of poor quality.</td>
<td>1.515</td>
<td>1.459</td>
<td>0.424</td>
</tr>
</tbody>
</table>

* Item response theory.

The reliability values for the SKILLD and HLAT-8 instruments were 0.756 and 0.511, respectively.

**DISCUSSION**

The analysis of the latent traits of knowledge about DM and HL by the IRT revealed difficulties of the participants in recognizing the signs and symptoms of hyperglycemia and hypoglycemia, as well as in finding health information on the Internet and understanding instruction leaflets for medication. These difficulties can be influential in the self-management of the disease, resulting in uncontrolled glycemic levels and increased complications. The study participants obtained high means of Hb1Ac and fasting glycemia. These findings are similar to those found in a study in the State of Bahia with 352 participants, which obtained a mean Hb1Ac of 8.7 ± 2.4 and fasting glycemia of 169.8 ± 74.13. It is reinforced that the sample investigated in the Bahian study was bigger than ours and that some participants had controlled glycemic levels.
The lack of glycemic control can be associated with several factors, such as the low number of visits by community health agents, not having comorbidities associated with DM, male gender, brown or black skin color, use of insulin, smoking, not having a private health plan, poor or very poor perception of health status, and middle-level occupation.

In the present study, family income was related to increased fasting blood glucose. It is inferred that people with better financial conditions can eat a diet rich in fruits, vegetables, grains, fibers, and dairy products, recommended by specialist societies for DM control. It is also considered that people with higher incomes can access public and private health services, possibly choosing the treatment modality that best fits their particular conditions.

Nevertheless, family income was also correlated with SKILLD scores. It can be inferred that persons with low financial incomes occupy positions in the labor market that require less educational training, and level of education is a factor that hinders the understanding of some aspects of DM. However, a study conducted in the South Region of Brazil with 80 subjects diagnosed with DM assessed knowledge about the disease and preventive measures for diabetic foot and showed that these measures were unrelated to education and income. Insufficient knowledge and the absence of preventive measures demonstrate gaps in care management. Our research findings reveal that the participants had difficulties with foot self-examination and identifying long-term disease complications.

Other items with a low latent trait SKILLD score were the ones related to recognizing the signs and symptoms of hyperglycemia and hypoglycemia and the normal Hb1Ac value. Similar findings were reported by a prior study on the translation and validation of the SKILLD instrument into Brazilian Portuguese, obtaining the lowest scores in these same questions, and by a study that applied the SKILLD instrument to Hispanic Americans with a lower percentage of correct answers in questions #1 and #8. Both the studies analyzed the SKILLD test by measuring the number of correct answers and failures, not evaluating the difficulty of questions answered correctly, as we did in the present study.

An American study assessed the performance of 593 elderly answering the Short Diabetes Knowledge Instrument (SDKI) using IRT. Similar to our results, the participants presented the lowest percentage of correct answers and the lowest latent variable in the question related to the signs and symptoms of hyperglycemia. Another study applied the IRT to evaluate the psychometric properties of the Diabetes Knowledge Test (DKT) and revealed that the most difficult item was the one related to the treatment of low blood glucose, diverging from our findings since this item obtained the highest latent variable value.

Lack of knowledge about some aspects of the disease, considered basic, may be associated with access to health services and the acceptability of the disease. Various supply/demand barriers involving health services are mentioned, such as lack of accessibility due to the lack of transportation or cost of displacement, lack of professionals, lack of information, delay in meeting the patient's needs, and low acceptability related to poor receptivity, beliefs related to the non-existence of the disease, stigmas and preference for alternative therapies.

Lack of clarity about the real conditions of DM may result from a conception based on common sense, which negatively impacts the management of the signs and symptoms of the
disease. Consequently, there is an increased risk of complications.22 This indicates the need to assess the influence of the communication used in professional guidelines and the information in health forms since the study participants achieved low HLAT-8 average scores in these subjects.

A prior study that validated the HL instrument for the Chinese language showed that the highest average was obtained in the item about understanding instruction leaflets for medication.23 It should be noted that, in the Chinese validation, the instrument was applied to adolescents, and our research participants were adults with a high average age and medium educational level. A prior systematic review analyzed the readability of package leaflets of medicinal products. The review highlights the lack of clarity regarding the instructions, lettering, and illustrations in reduced sizes, the absence of tests of understanding of patients without prior analysis of the level of HL, the knowledge of medical terms, and cognitive factors, which can negatively impact people's health.24

The HLAT-8 item with the lowest average difficulty referred to the ability to identify high quality internet sources. The Internet has become a promising source in the search for health information and has shown benefits in coping with chronic diseases by helping to reduce overweight, providing health education, self-care, and knowledge about therapeutic possibilities.25 However, not all information available on the Internet is reliable, which can cause misinformation and negatively influence health-related choices.26 There are specific instruments to measure digital HL levels, such as the eHealth Literacy Scale (eHEALS), which has been translated and validated into Brazilian Portuguese.27

The eHEALS Brazilian version has good discrimination values obtained through IRT. The questions with the lowest averages were about evaluating health resources found on the internet, the quality of internet information, which health sources are available, and differentiating high-quality health resources from low-quality ones, revealing the participants' greatest difficulties in accessing online information.27

IRT analysis helps clarify the users' greatest difficulties or facilities, with the possibility of developing actions aimed at these gaps. However, the instruments used must present a discrimination parameter greater than two and less than four to assess the difficulty/ease of responding to the item by the slope of the ICC.2

In this sense, it was found that items #3, #4, and #6 of the HL instrument presented discrimination below zero, indicating that they do not have the power to distinguish whether the participant got the item right because he knew how to answer it or by chance.7 The reliability of the HLAT-8 tool for the adult population was below the recommended value.28

SKILLD's Cronbach's alpha value indicates good application for adults since the Brazilian Portuguese language was validated in an elderly population.11 Also, there was no correlation between age and the difficulty or ease of responding to the instrument's items.

This research was limited by the difficulty of finding studies on knowledge and HL in people with DM using the IRT. It was verified that the use of the IRT in health is focused on creating and validating instruments, which deprived the comparison of research findings. Another limitation is the convenience sampling, which resulted in the predominance of older women.
CONCLUSION

The analysis of the latent traits of knowledge about DM and HL through the IRT made it possible to understand the participants’ difficulties in answering the questions with greater clarity, demonstrating the gaps in the control and self-management of the disease. Some examples include the lack of understanding or non-recognition of the signs and symptoms of hyperglycemia/hypoglycemia, the lack of understanding of the information in the package leaflets of medicinal products, and the lack of knowing how to define high-quality sources of information on the Internet.

Recognizing the aspects above can provide subsidies for the performance of health and nursing professionals in directing educational actions to promote health and prevent disease complications. Researchers and professionals encourage the use of the IRT to identify the latent traits of validated instruments, understand the real gaps in DM management, and propose targeted and assertive interventions to encourage self-management.

CONTRIBUTIONS

The authors contributed equally to the design of the research project, data collection, analysis, discussion, and the writing and critical review of the manuscript's content, with intellectual contribution and approval of the final version of the study.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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