

Improving Nutrition Risk Screening for Community-Dwelling Frail Older Adults

by

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AUTHOR'S DECLARATION

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

STATEMENT OF CONTRIBUTIONS

This thesis consists in part of two manuscripts that have been prepared for publication.

Exceptions to sole authorship include:

Chapter 4: Meagan S. Jackson, Sharon I. Kirkpatrick, Alex Wong, Heather H. Keller.

Confirming and Refining SCREEN for a Frail Population: A Delphi Study

Chapter 5: Meagan S. Jackson, Sharon I. Kirkpatrick, Marina Mourtzakis, Martin A.

Holmes, Heather H. Keller. Creating an Alternative Brief SCREEN using Nutri-eSCREEN

As lead author of these two chapters, I was responsible for conducting the data analysis, and drafting the manuscripts. My coauthors provided guidance during the research process and provided feedback on draft manuscripts, with significant editorial contributions from my advisor, Dr. Heather Keller.

Under Dr. Heather Keller's supervision, the papers prepared in this thesis are intended to be submitted for publication.

ABSTRACT

Background: As Canada's population continues to age, it is essential to screen for nutrition risk in frail older adults to support older adults to benefit from services and care that can improve their nutrition and prevent outcomes of nutrition risk, such as frailty. Frailty is defined as "an age-related syndrome of physiological decline, characterized by marked vulnerability to adverse health outcomes" (Walston et al., 2022). Over time, insufficient protein and energy intake may increase the risk of malnutrition (Hoogendijk et al., 2019) and may lead to weight loss in an older population, which is an indicator of frailty (Cederholm et al., 2019; Fried et al., 2001; Wei et al., 2018). The Seniors in the Community Risk Evaluation for Eating and Nutrition (SCREEN)-14 is a 17-item questionnaire created to measure nutrition risk in older adults aged 50+ (Keller et al., 2005). As SCREEN was created before frailty became a relevant concept in clinical care, refinements to SCREEN-14 may be needed to specifically target frail older adults. Further, to promote use of nutrition screening tools in practice, they need to be as brief as possible. SCREEN-8 was developed using a mixed method of classical test theory and expert opinion to meet this need. However, it is not known if this is the best short version of the tool, specifically considering frail older adults.

Objectives: The objectives of this thesis were to: (1) use expert opinion to determine the minimum set of SCREEN-14 questions needed to identify nutrition risk in potentially frail older adults (i.e., content validity), and if any new questions are required (**Chapter 4**) (2) use Item Response Theory (IRT) to also identify a minimum data set that can differentiate those most likely to be at risk, and specifically within the oldest age groups (proxy for frailty) (**Chapter 5**), and (3) evaluate the differences and overlap in these tools as compared to SCREEN-8. (**Chapter 5**). Two discrete studies will be completed to address these objectives.

Methods and results: The first study (**Chapter 4**) uses a Delphi technique which gathers expert opinion and builds consensus on an issue by way of anonymous surveys. Forty-six experts in the field who have used SCREEN in the past and had contacted the originator were invited to participate in a two-round Delphi process. Eighteen experts participated throughout the two rounds. They were asked to rate (first round survey) and confirm (second round survey) the importance of current SCREEN-14 items for the inclusion in a minimum set that specifically could identify risk in those who are frail. Additional questions were asked on expansion of items (round one) and consensus on inclusion of new items (round two). The experts concluded that eight current SCREEN questions should be included in the final set with no new questions added.

The second study (**Chapter 5**) addresses objectives two and three in a secondary data analysis of the Nutri-eSCREEN dataset. Nutri-eSCREEN contained SCREEN-14 in an online platform as well as self-reported sex, age, and geographic location. After cleaning and applying the exclusion criteria there were $n=20,093$ participants in the dataset used in the analyses. To address objective two, psychometric models, specifically a Graded Response Model (GRM) was conducted to identify a draft minimum SCREEN (i.e., what items discriminate risk) using the whole sample as well as only participants 75+years ($n=2,749$) to serve as a proxy for frailty. From both samples eight different questions (six of them overlapping) were identified using the item parameter estimates and consideration on coverage of the concept of nutrition risk. The IRT 75+ version was decided to be a better tool and used in subsequent analyses. Using demographic variables, a bivariate analysis was also completed to determine the statistical differences among SCREEN-14 questions by sex and age groups to demonstrate construct validity of the abbreviated IRT version. Variations of SCREEN (SCREEN-8 and SCREEN resulting from the Delphi) were created for comparison to this IRT version resulting from the GRM analysis to address objective three. SCREEN-8 identified the highest proportion at risk (42.1%) and the SCREEN-IRT the least (27.7%). The overlap of all three versions identifying participants to be at risk was 77.4%. Finally, model fit statistics among the three brief versions were calculated with SCREEN-8 and SCREEN-IRT found to be better tools than SCREEN-Frail.

Conclusion: As the population is rapidly aging, easy to use and brief tools that target nutrition risk identification to those most in need of further evaluation are required. These studies helped to identify two separate potential versions of SCREEN through different methods. The different versions both contained eight questions as does SCREEN-8. The conclusion is that although these two new versions were created via consensus and IRT methods they do not appear to be superior to SCREEN-8 with respect to, brevity, model fit, and identification of prevalence of risk. Future work should further test and validate these versions for comparison to SCREEN-8.

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LIST OF ABBREVIATIONS

SCREEN Seniors in the Community Risk Evaluation for Eating and Nutrition

ESPEN European Society of Clinical Nutrition and Metabolism

MNA- SF Mini Nutritional Assessment Short-Form

MNA/ MNA-FF Mini Nutritional Assessment Full-Form

BMI Body Mass Index

SNAQ 65+ Simplified Nutritional Appetite Questionnaire

ORE Office of Research Ethics

SD Standard Deviation

IRT Item Response Theory

IRCCC Item Response Category Characteristic Curves

GRM Graded Response Model

ANOVA Analysis of Variance

KW Kruskal – Wallis

TIF Test Information Function

RMSEA Root Mean Square Error of Approximation

SRMSR Standardized Root Mean Square Residual

TLI Tucker-Lewis Index

CFI Comparative Fit Index

OVERVIEW OF WORK

The introductory chapter provides background information to the relevance and importance of doing this research. It also defines the population this research aims to help. Chapter 2 highlights relevant literature, to emphasize the importance of proper nutrition risk screening tools in the community, specifically on frail older adults. Chapter 3 provides the research objectives along with the research questions. Chapters 4 and 5 are individual studies written in a manuscript style. Finally, chapter 6 is the overall discussion of this thesis, providing a conclusion on this work.

CHAPTER 1: INTRODUCTION

As Canada's aging population continues to grow, it is becoming increasingly important to identify those who have health risks and conditions to provide services and supports that can improve their overall health and well-being. Frailty is one of these conditions and can be defined as "an age-related syndrome of physiological decline, characterized by marked vulnerability to adverse health outcomes" such as falls, bone fractures, hospitalizations, and mortality (Walston et al., 2023). Rockwood's accumulation of deficits model suggests that frailty is a non-specific vulnerability, and there are many factors that lead to a frail state (Rockwood & Mitnitski, 2007). Regardless of the factors that lead to frailty, frail older adults are less likely to adapt and/or recover from chronic injuries or disabilities (Fried et al., 2021). Early identification for frailty is crucial, specifically in adults aged 50 and over when treatments may benefit and reverse frailty (Abbasi et al., 2018). The current prevalence of frailty in Canada is 1.2 million (2017) older adults, which is approximately 25% of those over the age of 65; frailty increases with age as half of those over the age of 80 have been identified as frail (Canadian Frailty Network, 2019). It is projected by 2025 that the prevalence of frailty will be over two million Canadians (Canadian Frailty Network, 2019), thus increasing the demand for frailty prevention and/or delay of progression.

In the definition of frailty, it is noted as a syndrome and not a disease state which alludes to the idea that frailty is dynamic and can improve with interventions like nutrition support (Ni Lochlainn et al., 2021). Nutrition plays a key role in 'successful aging' (Berrut et al., 2013; Young et al., 2009) such as improving disease burden, increasing physical and mental functioning, as well as social functioning (e.g., mealtime socialization) (Fekete et al., 2022). Long-term (over four or five years) poor food intake, specifically in the older population, can lead to insufficient protein and energy intake (Liang et al., 2021). Overtime, this can lead to weight loss, an indicator of frailty (Fried et al., 2001; Wei et al., 2018) as well as malnutrition (Buhl et al., 2022; Cederholm et al., 2019; Laur et al., 2017). Thus, early identification of those who have nutrition problems, such as low intake of key food groups, especially in those who are at greatest risk for frailty (e.g. over the age of 75 years), is important for improving their overall health and well-being.

SCREEN (Seniors in the Community: Risk Evaluation for Eating and Nutrition) was created almost 25 years ago as a tool to determine nutrition risk in those over the age of 50 years (Keller et al., 2000). Since SCREEN's original creation it has gone through adaptations to abbreviate (SCREEN-8, and SCREEN-3; Keller et al., 2005; Morrison et al., 2019) to promote use in clinical settings. Further testing of SCREEN-14 is warranted as frailty has become an increasingly relevant condition. Recent evidence

demonstrates that SCREEN-8 predicts strength and physical performance change over a three-year period (Keller & Trinca, 2023). However, consensus on what questions should be included in a tool to specifically identify nutrition risk in frail older adults is not yet available.

CHAPTER 2: LITERATURE REVIEW

2.1 Frailty, Malnutrition, and Nutrition Risk

Both frailty and malnutrition are individual health ailments, but they have extensive overlap in both construct, diagnosis, and treatment. Malnutrition is defined as “a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease” (Cederholm et al., 2016). The European Society of Clinical Nutrition and Metabolism (ESPEN) guidelines identify that frailty is a separate condition from, but is often associated with, malnutrition (Cederholm et al., 2016). Nutrition risk is defined by the risk of poor nutritional status, lying on the continuum between nutritional health and malnutrition (Dent et al., 2023; Ramage-Morin & Garriguet, 2013).

There are many contributing factors to poor nutritional status especially in aging adults such as age-related physiological changes, diseases, medications, and social and economic constraints, to name a few (Dent et al., 2023; Fávaro-Moreira et al., 2016; Ramage-Morin & Garriguet, 2013; Volkert et al., 2019). The factors that are associated with poor nutrition/nutrition risk are often very similar to those associated with frailty, such as age (those over 75 have a higher risk), sex (specifically female), or are part of the deficit compilation that is considered for identifying frailty in older adults

(e.g. sensory loss, more disease conditions, anemia, loss of teeth, changes in mobility, loss of social network) (Lang et al., 2009; Pérez-Ros et al., 2020; Rockwood & Mitnitski, 2007). In addition to the similar risk factors for frailty and malnutrition, there are also similar characteristics with respect to changes in body composition (e.g. a loss of body tissue, both fat and muscle). This can result in negative outcomes such as increased risk of falls, poor quality of life, and increased risk of mortality (AlMohaisen et al., 2022; Jeejeebhoy, 2012). The overall conclusion is that there is a strong correlation between poor nutrition and frailty (Laur et al., 2017; Laur et al., 2020; Pérez-Ros et al., 2020; Wei et al., 2018).

Although nutrition risk is the beginning stage that could potentially lead to malnutrition, it is not measured in the same way as malnutrition. Once a patient has been detected with nutrition risk, typically measured with a brief tool, they undergo a comprehensive nutritional assessment to identify the course of action and degree of malnutrition (Serón-Arbeloa et al., 2022). Having a screening tool that is easy to use and understand makes it simple for community-dwelling older adults to complete and if interventions are put into place, prevent the downside to malnutrition. In Canada the prevalence of high nutrition risk in community-dwelling older adults over 65 years of age is 34% using data from 2008/2009 (Ramage-Morin & Garriguet, 2013). More recently, there is evidence to show that one third of the community dwelling older Canadians

have nutrition risk according to SCREEN-8 (Keller & Trinca, 2023; Ramage-Morin et al., 2017).

Nutritional status is a modifiable risk factor for frailty, therefore maintaining a good nutritional status can help aid in the prevention of frailty (Ni Lochlainn et al., 2021; Bardon et al., 2021). Determining and treating frailty is becoming a priority in health care and research (Bloom et al., 2022; Roberts et al., 2019). Due to the high prevalence of nutrition risk in older adults living in the community (Laur et al., 2017; Ramage-Morin & Garriguet, 2013), and commonly comorbid with frailty (Pérez-Ros et al., 2020), it is important to also screen for nutrition risk in those who are potentially frail (Bloom et al., 2022).

2.1.1 Macro- and Micro-nutrient Considerations with Frailty

Frailty is noted as a syndrome, where many deficits (e.g. sensory loss, disease states, medication usage, social changes) accumulate and lead to someone being frail (Rockwood & Mitnitski, 2007). A main contributor can be inadequate energy and nutrient intake (Gingrich et al., 2019) that results in weight loss and other nutritional deficits. In fact, in the phenotype definition of frailty, weight loss is considered an indicator (Fried et al., 2001). Optimal nutrition is not only important for the prevention and treatment of diseases, but it also helps to facilitate independence and overall, helps the population achieve healthy aging (Norman et al., 2021; Rudnicka et al., 2020). Yet,

there are important micro- and macro-nutrients that are commonly inadequately consumed by older adults, such as vitamin D, calcium, and most importantly, protein (Dent et al., 2019; Hernández Morante et al., 2019).

A review examined previously published literature on frailty and different factors involved in this overall syndrome, with a specific focus on the nutritional evidence (Hernández Morante et al., 2019). The greatest evidence is focused on the macronutrients and most notably, protein; those with a low protein intake are more likely to be frail (Dent et al., 2019; Hernández Morante et al., 2019). There are many different sources of protein both animal-based, and plant-based, although there are sufficient arguments on both sides for which type of protein is best when trying to prevent or delay the progression of frailty (Coelho-Junior et al., 2020; Coelho-Junior et al., 2022; Landi et al., 2016). Experts note that if you are achieving the daily minimum requirements of 1.0 to 1.2 g/kg/day for older adults (Deutz et al., 2014), then the type of protein source is not as critical, although animal-based protein is the best source from a quality (e.g. essential amino acids) perspective (Berrazaga et al., 2019). Overall, in the literature there is strong evidence that shows the association of protein intake with frailty status; thus, it is very important to the prevention or delay of frailty to consume the right amount of protein (Prado et al., 2022).

A further review also identified individual micronutrients that were independently associated with frailty; these were vitamins D, C, folate, and B6 (Lorenzo-López et al., 2017). As vitamin C, folate, and B6 are nutrients relatively common in a nutrient-dense diet, low intake of these nutrients and the association with frailty, suggests overall low food intake or a poor-quality diet (e.g. low in micronutrients) by these older adults. As adults get older, recommended dietary allowances for vitamin D increase due to the body's inability to synthesize vitamin D efficiently (Dodd, 2019). The recommended daily dosage for adults over the age of 70 of vitamin D is 800IU with 4000IU as the tolerable upper limit (Health Canada, 2021). As a result of this increased recommendation for intake, older adults typically do not consume enough vitamin D (Ter Borg et al., 2015; Vatanparast et al., 2020), causing this to be a nutrient of concern for this population. Similarly, the recommended calcium intake also increases as people age (Institute of Medicine, 2011). The recommended daily dosage for males 51-70 years is 1,000mg and for females it is 1,200mg, whereas for all over the age 70 years the recommendation is 1,200 mg daily (Health Canada, 2010). Older adults also commonly have a low intake of calcium from their diet (Ter Borg et al., 2015; Vatanparast et al., 2020).

As previously indicated, vitamin D and calcium have an influence on the frailty syndrome. Previous literature notes that vitamin D promotes strong bones, helps muscles to move, and has a role in keeping the immune system healthy (Meehan &

Penckofer, 2014). All these mechanisms of vitamin D can help reduce frailty or the severity of frailty (Buchebner et al., 2019). As people age, vitamin D is not easily synthesized by the skin from sunlight, and older adults tend to spend more time indoors and away from the sun (Meehan & Penckofer, 2014). Further, few foods are considered good sources of vitamin D. As a result, supplementation in older adults is needed (Buchebner et al., 2019; Cai et al., 2022). Vitamin D is also known to play a role in the absorption of calcium which can lead to reduced bone density and strength. Therefore, the need for increased vitamin D is crucial for potentially frail older adults (Buchebner et al., 2019; Cai et al., 2022). Along with vitamin D, calcium is also an important nutrient for frailty (Hernández Morante et al., 2019). There is not a lot of literature solely on calcium and its link to frailty; most literature focuses on the combined action of vitamin D and calcium (Hernández Morante et al., 2019). Nutrition risk tools that evaluate the intake of protein especially, and potentially key nutrients that are commonly poorly consumed (e.g., vitamin D and calcium) would be useful for helping to identify nutrition risk in potentially frail older adults.

2.2 Current Nutrition Risk Screening Tools

There are many nutrition risk screening tools circulating the globe, but not all are appropriate and have gone through the correct process for creation and testing (Power et al., 2018). One of the more popular valid and reliable tools is the Mini Nutritional

Assessment (MNA). There is a short-form (MNA-SF) that is considered a screening tool (6 questions: has food intake declined over the past three months due to loss of appetite, digestive problems, chewing or swallowing difficulties; weight loss during the last three months; mobility difficulties; suffered psychological stress or acute disease in the past three months; neuropsychological problems (e.g. dementia) and BMI or if BMI cannot be done then calf circumference (cm)). When all eighteen questions are completed, the MNA is considered a useful malnutrition assessment tool rather than a screening tool (Rubenstein et al., 2001). The MNA-SF has had an abundance of research that demonstrates good sensitivity and specificity (Guigoz & Vellas, 2021). Three studies have determined the sensitivity and specificity for the MNA-SF to be over 80% with kappa values of 0.6 or above, which shows good validity and interrater reliability (van Bokhorst-de van der Schueren et al., 2014). Although the statistics show that MNA-SF has good validity, it has only been validated against the full version of MNA, which results in criterion contamination (Power et al., 2018). There has also been a lot of research completed to validate the MNA in many populations and there is some contention that the tool can even be used to determine frailty (Dent et al., 2012; Power et al., 2018). A study conducted on the ability of MNA-SF to predict frailty in hospitalized patients concluded that the MNA-SF was a quick and easy tool that predicted both malnutrition (as measured by the MNA) and frailty (as measured by Fried's frailty criteria) in older adults admitted to the hospital (Dent et al., 2012). The tool however

includes anthropometric measures, which can limit its use as a screening tool in some clinical settings (Power et al., 2018) and results in the need for interviewer administration.

Another screening tool designed specifically for older adults is the Simplified Nutritional Appetite Questionnaire (SNAQ 65+). This screening tool is only composed of four questions pertaining to the patient's weight loss, mid-upper arm circumference, appetite and functionality (www.fightmalnutrition.eu). As this tool is very short in length, it is more commonly used in the community setting for determining risk of malnutrition in Europe (Wijnhoven et al., 2012). Predictive validity was studied with respect to six-year mortality and the Hazard Ratio was 2.46 for those in the 'at risk' of malnutrition group (Wijnhoven et al., 2012). Although predictive validity has been demonstrated, the concurrent criterion validity with a gold standard has not been tested which can affect the overall understanding of the validity of the tool in the community population (Keller et al., 2020; Power et al., 2018). The lowest evidence for validation is content, with the best being concurrent criterion validation; in the scope of malnutrition there is no defined gold standard, but a semi-gold standard is known as an in-depth nutrition assessment completed by a trained nutrition expert (Keller et al., 2020). As SNAQ65+ has not been compared against this semi-gold standard the validation is not as strong as other screening tools in practice (Power et al., 2018). Further, as anthropometric measures are required, this can limit its use in some community settings.

A nutrition risk screening tool that was developed in Canada is known as the SCREEN-14 (previously known as Seniors in the Community: Risk evaluation for eating and nutrition Version II). SCREEN was originally developed for research to assess the association of nutritional risk with health outcomes within the community (Keller et al., 2000) and can be self-administered as it is solely based on questions and requires no anthropometric measures. This increases the usefulness of SCREEN for epidemiological survey studies. This 17-item tool covers nutritional risk factors such as weight change, perception of body weight, skipping meals, avoidance of certain foods, two questions on intake of protein foods (meat and plant based proteins; dairy and soy alternatives), fruits and vegetables, and fluids, as well as issues with biting/chewing, usage of meal replacements, frequency of eating meals with other people, difficulty with meal preparation, and lastly, difficulty getting groceries (Keller et al., 2005). As compared to other screening tools, SCREEN includes questions that can address protein, calcium and vitamin D intake and identifies functional challenges that may be associated with frailty.

SNAQ 65+ and the MNA-SF do not contain specific questions regarding the intake of the food and specifically nutrients that are poorly consumed by older adults that may be associated with frailty (Hernández Morante et al., 2019). SCREEN has questions focused on high protein and calcium food choices, but not specifically vitamin D, as there are not many foods which are naturally rich in vitamin D. In Canada, there

are foods which are fortified with vitamin D such as margarine, meal replacements and nutritional supplements, different types of milk (skim, skim milk powder, etc.) goat's milk, and liquid eggs (Health Canada, 2024), but in other countries where SCREEN is also used, these fortified products may not exist. Further, it is recommended that those over the age of 50 years take a vitamin D supplement due to their increased requirement for vitamin D (Health Canada, 2022).

SCREEN has been previously compared to the MNA- SF in community dwelling seniors in Bosnia and Herzegovina (Pavlović et al., 2020). The conclusion of this study was that the MNA-SF has a limited role in the nutritional risk screening within the community sector, whereas SCREEN-14 has promising results. Further testing was recommended in different populations (Pavlović et al., 2020). SCREEN-14 has also been compared to SNAQ 65+. Final conclusions were that SCREEN-14 was more individualized to older adults, which can lead to tailored interventions (Borkent et al., 2020). It has also been suggested that at a population level there should be greater focus on common nutrition risk factors (Borkent et al., 2019), such as those included in SCREEN. The most frequently reported nutrition risk item on SCREEN in the study comparing SNAQ 65+ to SCREEN was the perception of body weight as being either too high or too low (Borkent et al., 2019). Unfortunately, when an older adult attempts to lose weight, they may also lose muscle mass if they do not have enough protein content in their diet (Villareal et al., 2005). Overall, the early determinants of nutrition risk are

better represented in SCREEN-14, whereas in SNAQ 65+ the late symptoms of malnutrition are identified (Borkent et al., 2019).

2.3 SCREEN Creation, Validation and Variations

SCREEN was originally created as a research tool to assess the association of nutrition risk with health outcomes in the community population (Keller et al., 2000). It was developed iteratively considering psychometric and clinical perspectives on nutrition risk and included older adults to support the identification and wording of items (Keller et al., 2000). Shortly after its original development, SCREEN went through both construct and criterion validation testing (Keller et al., 2000). For criterion validation, there needs to be a gold standard to compare the measurement to; in the case of nutritional risk screening there is no gold standard, therefore researchers must choose the next best thing, or a 'semi' gold standard (Cederholm et al., 2019; Keller et al., 2005). Due to the lack of a true gold standard, SCREEN was validated against a dietitian's assessment of nutrition risk (rating 1-10) based on medical history, weight history, anthropometric measures, and diet history for communality-dwelling older adults (Keller et al., 2000). The first version of SCREEN was modified to address concerns from users as well as to increase discriminate ability of items (Keller et al., 2000). SCREEN-II (now known as SCREEN-14) was compared to a dietitian's assessment of nutrition risk and the dietitian rating was used with Receiver Operator Characteristic

curves to determine sensitivity (84%) and specificity (62%) of SCREEN-14. Test-retest and inter-rater reliability as well as inter-modal reliability have also been completed on this version of SCREEN (Keller et al., 2005).

Since its creation, there has been demand for a shorter version or a ‘minimum set’ of SCREEN questions that can identify nutrition risk for use in clinical practice (Keller et al., 2005). In the validation of SCREEN-II (now known as SCREEN-14), an abbreviated version was also developed through statistical analysis (regression with the dietitian rating of nutrition risk) and expert ranking of the items (Keller et al., 2005). In the development of SCREEN, a group of dietitians had ranked twenty-three draft items to the importance of the construct of nutritional risk (Keller et al., 2005). Some items were double weighted in scoring, the dietitian experts thought they were the most important questions to determine the concept of nutrition risk. In the validation testing of SCREEN II, the eight-item abbreviated SCREEN was found to have a sensitivity of 84%, specificity of 58%, and a positive predictive value of 83% and a negative predictive value of 59% when compared to the semi-gold criterion of a dietitian’s risk rating (Keller et al., 2005). SCREEN-8 (previously known as SCREEN-II-AB) is commonly used in practice throughout Canada and has been used by Statistics Canada in surveys (Keller & Trinca, 2023; Morrison et al., 2019; Ramage-Morin et al., 2017). However, this version does not include the high protein and calcium food questions potentially important for frailty.

Despite the development of a valid and reliable SCREEN-8, there continued to be demand for an even shorter version of SCREEN. To address this demand, SCREEN was further tested. SCREEN-3 was originally created through construct validity of a three-item version of SCREEN-II-AB when compared with self-perceived health and diet perceptions in older Canadian community-dwelling males (Akhtar et al., 2015). The full SCREEN-14 was compared to the results of just three questions selected based on the early development of SCREEN by experts who indicated determining weight change, appetite, and swallowing difficulties as essential in any risk evaluation by a dietitian (Keller et al., 2005; Morrison et al., 2019). The constructs for comparison to SCREEN-3 were self-perceived health, diet healthiness, and the participants' rating of nutrition's importance to aging. The results of this initial study show that all construct items were significantly associated with SCREEN-14 and the three-item version (Akhtar et al., 2015).

Due to the limited number of items (three items), there is room for high misclassification of older adults with this version, either as falsely not having (false negative) or having nutrition risk (false positive) when they are either known to have or not have nutrition risk. SCREEN-3 was subsequently tested in a large data set with diverse outcomes, where SCREEN-8 had been used (Morrison et al., 2019). Misclassification of risk as compared to SCREEN-8 and construct validity were determined with self-reported health and hospitalization. Misclassification is important to

try and avoid in a screening tool; specifically, a false negative with SCREEN could result in an older adult continuing with their current dietary patterns which could lead to worsening their health and potentially causing irreversible damage (Reber et al., 2019). SCREEN-3 on its own was found to misclassify participants as being at nutrition risk (i.e., at nutrition risk when they were not; Morrison et al., 2019). A compromise was reached by re-ordering SCREEN-8 questions, so that the SCREEN-3 questions were asked first. If a participant had a high score on these three questions, it was unlikely the person would be at risk and the remaining five did not need to be asked. This SCREEN-3 Extended version is intended for primary care use to get a quick and easy understanding on if the person is at potential nutritional risk or not, and if they are detected to be at potential risk based on the first three questions, the remaining five questions in the SCREEN- 8 version would be completed to confirm this risk (Morrison et al., 2019).

Despite this careful development and testing of SCREEN, there are concerns about the lack of specificity of SCREEN (Borkent et al., 2019; Haakma & Wham, 2015; Morrison et al., 2019), resulting in higher prevalence of nutrition risk, that cannot be addressed with current services, such as dietitians, to assess and treat older adults (Donnelly & Keller, 2021). In a study conducted in the Netherlands, there was evidence to show that the prevalence of nutrition risk is higher when SCREEN is used when compared to SNAQ 65+, likely as a result of the items included in these two tools

(Haakma & Wham, 2015). Another study used to validate SCREEN-14 in New Zealand (Wham et al., 2014) showed that SCREEN had a higher sensitivity and specificity as compared to the original validation study of SCREEN-II (Keller et al., 2005), but this was likely due to the scope of their exclusion criteria (limited to those 85-86 years) and the difference in methodology (Wham et al., 2014). Specifically, in the original validation of SCREEN it was self-administered (Keller et al., 2005) among participants whereas in this New Zealand study it was interview administered which could result in the difference of specificity (Wham et al., 2014). These issues raise the potential for considering how SCREEN-14 can be further refined to target those most in need of nutrition services, those who are potentially frail.

2.4 Summary of Literature Review

Frailty is “an age-related syndrome of physiological decline, characterized by marked vulnerability to adverse health outcomes” (Walston et al., 2018). There are many factors associated with frailty, but poor nutrition is a driving factor to becoming frail (AlMohaisen et al., 2022; Bloom et al., 2022; Buhl et al., 2022; Cederholm et al., 2016). Many nutrients are associated with frailty and if they are lacking in the older adult’s diet, they may perpetuate frailty. Key nutrients which are often poorly consumed and linked to bone and muscle as well as overall health are protein, calcium, and vitamin D (Hernández Morante et al., 2019). There are a variety of nutrition risk

screening tools, however, most do not include food intake items that can provide a sense of these three nutrients. The SCREEN tool does have the capacity to elicit risk due to protein and calcium intake from consumption of foods that contain these nutrients. All the current SCREEN versions have the intended purpose of identifying nutrition risk in older adults, but the abbreviated versions have their limitations in development and testing. It is still questioned if a better minimum version of questions from SCREEN-14 is possible and if it can be specifically targeted to those most in need, those at nutrition risk who are also potentially frail older adults living in the community.

CHAPTER 3: RESEARCH QUESTIONS

3.1 Objective

To develop and test for content and construct validity, shortened versions of SCREEN-14 that can identify nutrition risk in potentially frail older adults and compare these versions to SCREEN-8.

3.2 Research Questions

1. What is the expert consensus (i.e., content validity) on the minimum set of SCREEN-14 questions that should be used to measure nutrition risk in those who are frail? Are new SCREEN questions required to further identify nutrition risk in frail older adults?
2. What minimum set of items from SCREEN-14 are identified using the psychometric approach of Item Response Theory? Is this minimum set different if only those 75+ years of age are included in the analysis?
3. What are the differences by age and sex (discriminant validity) and overlap in identification of nutrition risk between these new versions (developed in question 1 and 2) and the original SCREEN-8 (e.g., items, prevalence, and same individuals identified)?

CHAPTER 4: CONFIRMING AND REFINING SCREEN FOR A FRAIL POPULATION: A DELPHI STUDY

Target Journal: undecided

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4.1 Overview

Background

Frail older adults are at a greater likelihood of having poor nutrition or risk for malnutrition, yet no nutrition risk tool has been created specifically for this group.

Objective

The objective of this study was to determine how the current SCREEN-14 nutrition risk screening tool could be refined to screen for nutrition risk in frail older adults living in the community.

Design

A Delphi method was used to achieve content validity with experts in the field of older adult nutrition, who had previous experience with SCREEN-14. The Delphi was conducted through an online anonymous survey using two rounds. Existing knowledge though previous literature about the nutritional factors associated with frailty and SCREEN-14 usage helped to inform the Delphi questions and response options.

Participants/setting

Forty-six experts were contacted to be a part of the study, Of the forty-six, only forty-three were eligible to participate and a total of eighteen experts responded. Of the

eighteen, twelve participants completed round one (27.9% response rate), and fifteen completed round two (34.9% response rate); nine out of the fifteen were returning from round one (60% of participants). The two rounds of the Delphi were completed using Qualtrics (Provo, Ut). This survey contained study details, consent forms, the SCREEN-14 tool, demographic information questions, and questions pertaining to SCREEN-14. Data was collected between February and May 2023.

Results

After two rounds of the Delphi, experts reached consensus on eight questions from SCREEN-1 that they believed would better identify nutrition risk in frail older adults. No new questions reached consensus for addition.

Conclusions

These findings provide a new brief version of SCREEN, named SCREEN-Frail. The eight questions identified have four overlapping with SCREEN-8. The remaining questions are geared towards a frail older adult and include items on consumption of protein and dairy products.

4.2 Introduction

Screening for nutrition risk in frail older adults is key to optimizing early identification and subsequent services and treatment that can support nutritional recovery and potentially improve health (Keller & Trinca, 2023; Laur & Keller, 2017; Valentini et al., 2018). Previous literature indicates the importance for sufficient protein, calcium, and vitamin D in preventing and delaying the progression of frailty (Bucheberner et al., 2019; Coelho-Junior et al., 2020; Coelho-Junior et al., 2022; Hernández Morante et al., 2019; Landi et al., 2016; Ni Lochlainn et al., 2021; Prado et al., 2022). A nutrition risk screening tool that identifies risk in frail older adults should consider assessing consumption of these nutrients, as well as key factors associated with nutrition risk in frail older adults. With these nutritional indicators of frailty in mind, SCREEN-14 is a potential candidate tool for risk identification in frail older adults.

SCREEN-14 has been through validation for the general older adult population (Keller et al., 2005) and the original version has demonstrated predictive validity for mortality and health related quality of life in older adults who use community services like meal programs (Keller et al., 2004; Keller et al., 2005). However, modification may be needed to make the tool more specific to the frail population, especially as a high prevalence of risk is noted among the oldest age groups (Keller, 2015). As compared to other screening tools, SCREEN-14 has questions pertaining to daily consumption of high protein foods and dairy products, which are high in calcium. Furthermore, there

have been studies comparing SCREEN-14 to different nutritional risk screeners such as MNA-SF and SNAQ⁶⁵⁺ (Borkent et al., 2020; Pavlović et al., 2020). SCREEN-14 was preferred due to its form of criterion validation, consideration of over and undernutrition, as well as inclusivity of risk factors and different determinants that impact food intake (Borkent et al., 2020; Borkent et al., 2019).

Along with the SCREEN-14 version there is also an abbreviated version (SCREEN-8) which has undergone validity and reliability testing (Keller et al., 2005). This version was created due to clinical and research demand to have a shorter version. SCREEN-8 predicts relevant outcomes (Morrison et al., 2019) and has been used extensively in research and practice. However, it does not contain the items on high protein or dairy foods that may be beneficial for determining nutrition risk in potentially frail older adults.

The aims of this study were to determine consensus, from a group of experts familiar with SCREEN-14, on a) whether this tool should be used in its entirety to determine nutrition risk in frail older adults, b) if questions can be eliminated, and c) if new questions are required to further identify nutrition risk in frail older adults. The ultimate objective of this study was to determine the best subset of core questions for SCREEN that can be constituted and used to identify nutrition risk in a frail group of older adults. When developing or altering a tool to support clinical practice, seeking the

opinion of experts is a common approach (Barrett & Heale, 2020). The objective and aims were carried out through a modified Delphi method.

4.3 Methods

The Delphi process is a consensus-based method that gathers expert opinion to address a specific issue, refine questionnaires or develop guidance in areas where there is a lack of evidence (Niederberger & Spranger, 2020; Santaguida et al., 2018). A Delphi also uses collective intelligence from experts in an area that has conflicting or lack of evidence (Nasa et al., 2021). The Delphi method was chosen as the best method of gathering opinions for this study based on its previous use for research in the field of health (Nasa et al., 2021). A Delphi consists of two or more rounds of questions asked of experts anonymously. Multiple rounds provide an opportunity to become more specific with questions based on the information gathered from the previous round and allows the experts to evolve into developing a consensus on the issue (Barrett & Heale, 2020). Multiple rounds also allow the participants to reconsider their responses when viewed in combination with other experts' responses (Barrett & Heale, 2020). The on-line Delphi is a widely used approach because it gathers opinion in a way which provides anonymous and simultaneous responses from a wide geographical location (Keller et al., 2015). Consensus on inclusion of SCREEN items was defined at 80%

agreement rate or higher among participants (Diamond et al., 2014; Gattrell et al., 2022; Vogel et al., 2019).

4.3.1 Creation of the Questionnaires

A total of two rounds were conducted which was sufficient to attain consensus from experts to create SCREEN-Frail. The creation of the Delphi questions presented in the first round was based on previous knowledge of SCREEN and allowed invited experts to identify the SCREEN questions/issues that needed to be included in the potential refined version specific to frail older adults. The questions were focused on creating a nutrition risk screening tool that was as short as possible but still effective in picking up nutrition risk in frail older adults. Delphi questions were created by the research team through several iterations. The first survey was open for approximately four weeks. Once all the responses and comments were gathered from the first round, a new set of questions was developed by the research team for the second round of the Delphi. All original invitees were included in the second round, due to ethics requirements that the respondents remain anonymous. Thus, even people who did not respond in the first round were still sent the second-round survey.

The types of questions that were in the surveys were 7-point Likert scales, open text questions, multiple choice, and matrix questions. In round one of the Delphi, panellists were asked to rate their confidence (scale of 1 low to 7 high) in the current

SCREEN-14 tool to determine nutrition risk in the frail population (e.g. older adults who might require community services, have limited mobility, etc.). This was followed by asking participants to identify which SCREEN questions were required for inclusion in a tool specific to determining nutrition risk in frail older adults. All seventeen SCREEN questions were provided in a matrix for the participants to indicate which questions should be included in the final set (answers that could be selected were: unnecessary, somewhat necessary, or absolutely necessary and prefer not to answer). The next question in the survey was similar to the previous, except it was asking the experts to distinguish between the SCREEN questions that would trigger nutrition risk or not trigger risk for frail older adults. Subsequently, the next question asked participants to rate the high protein foods and the use of milk products or fortified soy beverages questions to adequately determine potential risk in frail older adults due to low protein intake (1= not adequate 7= very adequate). Similarly, the fifth and sixth questions in the survey asked the experts to rate the adequacy of the current SCREEN question on use of milk products or fortified soy beverages to determine potential risk in frail older adults due to low calcium intake and low vitamin D intake (1=not adequate 7=very adequate). The final two questions in round one were open-text focused on the experts' thoughts on changing any of the current questions and adding any additional questions to SCREEN, such as an item focused on vitamin D supplementation.

For the questions two and three that reached our criteria of 80% for agreement in the first round, Delphi participants were then asked to confirm these SCREEN questions in the second round and asked additional questions that were related to their comments from round one. Specifically, two questions were posed on vitamin D and calcium supplementation, and if it was necessary to include a new question on vitamin D or calcium supplementation in SCREEN. The scale for these questions was set at 1= unnecessary to 7= absolutely necessary. Two further questions were asked on the format of the potential new supplementation questions. The first format was focused on the actual dosage of vitamin D or calcium and the second option was a simplified 'yes' or 'no' question on if the older adult takes these supplements. These two formats were multiple choice options where experts indicated their preference for question format. Although there were a few comments about including financial stability in SCREEN in round one, questions on this issue were not included in the second round as it was considered out of the scope for SCREEN.

The Delphi for this study was carried out through an online survey platform, Qualtrics (Provo, UT). The questionnaire also captured demographic information such as age, gender identity, racial/ethnic identity, region of employment, and usage of SCREEN in the past. If a participant only completed round two, they were asked to complete the demographic questions in that round. The platform was tested by the first author, other members of the research team and members of the Nutrition and Aging

Lab until the questions and response options worked as designed. At the end of the survey, the participants were thanked and reminded of the subsequent version to come (for round one only). At the end of the round two survey, the participants were thanked for completing the round and informed of how to receive the summary of the findings.

4.3.2 Participants

Experts were defined to be researchers and providers who had recent experience with SCREEN. Potential participants were identified through previous email communication around using or attaining permission to use the tool with the originator of SCREEN between 2019 and 2022. An original forty-six potential participants were identified through this mechanism. Two emails were identified to be no longer valid. All participants that were identified were invited to complete both rounds of the Delphi survey, unless they had indicated they wanted to receive no further information about the study. One email participant indicated they no longer worked in seniors' nutrition and was not sent an invitation for the second survey. Although there is no set standard for the sample size of a Delphi, it has been suggested that a minimum number of twelve panel members is generally sufficient to achieve consensus, although larger sample sizes can improve the validity of the findings (Chalmers & Armour, 2019; Vogel et al., 2019). Of the forty-three experts eligible to participate in this Delphi study, a total of eighteen experts responded. Of the eighteen, twelve participants completed round one

(27.9% response rate), and fifteen completed round two (34.9% response rate); nine out of the fifteen were returning from round one (60% of participants). **Table 1** presents the demographic characteristics of participants. There was a high proportion of women (88.9%) with the largest age group being 40-55 years old (50%). Over half had a white ethnic background from both North America and Europe and worked in both Canada and Europe. Finally, most of the participants (77.8%) used SCREEN-14 as a part of their research.

Table 1 Demographics of Participants

Delphi Rounds	Round 1		Round 2**		Total	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Gender						
Women	10	83.3	6	100	16	88.9
Man	2	16.7	0	0	2	11.1
Age Group						
26-39 years old	3	25	2	33.3	5	27.8
40-55 years old	7	58.3	2	33.3	9	50
56+	2	16.7	2	33.3	4	22.2
Ethnic Background						
White – European	5	41.7	2	33.3	7	38.9
White – North America	3	25	3	50	6	33.3
Asian - East	1	8.3	0	0	1	5.5
Métis, White - North American (e.g., Canadian, American)	0	0	1	16.7	1	5.5
Prefer to self-describe	2	16.7	0	0	2	11.1 ^a
Prefer not to answer	1	8.3	0	0	1	5.5
Region of employment						
Canada	4	33.3	4	66.7	8	44.5
Europe	5	41.7	0	0	5	27.8
Australia and Oceania	2	16.7	1	16.7	3	16.7
Southeastern Asia	1	8.33	0	0	1	5.5
Other North America	0	0	1	16.7	1	5.5
Usage of SCREEN*						
Research	10	83.3	4	66.7	14	77.8
As part of managing others to conduct nutrition screening	2	16.7	0	0	2	11.1
Clinical Practice	0	0	3	50	3	16.7
Have not used SCREEN in research or Practice	1	8.3	0	0	1	5.5

*Option for more than 1 response per participant

** Demographics for round 2 are only the new participants who had not completed round 1

^a prefer to describe as, Türk and White-Australian

4.3.4 Data Collection

Delphi responses were collected from February 21st, 2023 to March 19th, 2023, for the first round and the second round was conducted from April 24th, 2023 to May 5th, 2023. The surveys were only available in English and only the first author had access to the data. Ethics review and approval was obtained from the University of Waterloo Office of Research Ethics (ORE #44963).

4.4 Results

On a Likert scale rated 1-7 on the confidence of SCREEN-14 to identify nutrition risk in frail older adults, the mean was 5.17 (SD 1.14) and five of the twelve participants (41.7%) ranked their confidence at a 6 or 7, indicating a high confidence level in the full screening tool to identify nutrition risk for the frail population. The next few questions were focused on identifying a minimum set of SCREEN questions for a potentially frail population. **Table 2** provides a summary of ratings for the SCREEN questions that reached an 80% consensus as candidates for a shorter version. In **Table 3**, there is a list of the SCREEN questions that did not achieve this level of rating for inclusion. **Tables 2 & 3** also contain the rating of the trigger question from round 1 and the subsequent confirmation for inclusion in round two. For round two, items to include were confirmed, however, only two items to exclude reached agreement at the 80% criterion.

Table 2 SCREEN Questions that Reached Consensus for Inclusion

SCREEN Questions	Round 1		Round 2 Questions Confirmed
	Very Necessary to include in final set (%)	Would trigger nutrition risk in frail older adults (%)	Include in final set (%)
Has your weight changed in the past 6 months?	91.7	91.7	93
Do you skip meals?	91.7	91.7	93
How would you describe your appetite?	83.3	100	86.7
How often do you eat meat, eggs, fish, poultry, tofu, dried peas, beans, lentils, nuts, or nut butters?	91.7	100	86.7
How often do you have milk, soy beverages, or milk products such as cheese, yogurt, or kefir?	83.3	66.7	80
Do you cough, choke or have pain when swallowing food OR fluids?	83.3	83.3	80
Is biting or chewing food difficult for you?	75	83.3	80
Do you have any problems getting your groceries?	66.7	75	80

Table 3 SCREEN Questions that were excluded from final set

SCREEN Item	Round 1		Round 2 Confirmed to Exclude
	Very Necessary to include in final set (%)	Would trigger nutrition risk in frail older adults (%)	Exclude from final set (%)
Have you been trying to change your weight in the past 6 months?	58.3	66.7	46.7
Do you think your weight is...?	16.7	33.3	86.7
Do you limit or avoid certain foods?	50	50	53.3
How many pieces or servings of vegetables and fruit do you eat in a day?	58.3	41.7	53.3
How much fluid do you drink in a day? Examples are water, tea, coffee, herbal drinks, juice, and soft drinks, but NOT alcohol.	58.3	66.7	33.3
Do you use commercial meal replacements or supplements? Examples are shakes, puddings, or energy bars.	41.7	33.3	60
Do you eat one or more meals a day with someone?	58.3	50	60
Who usually prepares your meals?	25	25	80
Which statement best describes meal preparation for you?	25	33.3	66.7

In round one, participants were asked to rate the extent to which they thought the current questions on high protein foods and milk/fortified soy product could adequately

determine the potential risk in frail older adults due to low protein intake. They were similarly asked about the milk/fortified soy product question identifying risk first due to low calcium and next due to low vitamin D intake (scale 1-7). The mean rating for if the two protein-focused SCREEN items could represent protein intake in frail older adults was 4.92 (SD 1.11) and the median was 4.5, indicating that participants generally felt these two questions together could adequately determine risk as a result of low protein intake in older adults. For the milk/soy product question representing risk due to low calcium intake the mean was 4.42 (SD 0.95) and the median was 4. Lastly, experts were asked to rate if the milk/soy products consumption question could adequately determine risk in older adults due to low vitamin D intake. The mean was rated at 3.42 (SD 1.04) with a median of 2.5, and it was concluded that this question was not adequate to identify risk due to low vitamin D.

In round two, participants were asked to rate a question on calcium supplement intake suggested by participants in round one as a useful addition to a shorter version of SCREEN. The participants reported their preference with a Likert rating of 1-7. The mean was rated at 3.21 (SD 1.52), which indicates that the participants found that the calcium supplementation question was somewhat necessary to unnecessary to include in the final set of SCREEN questions. Some round one participants suggested a vitamin D supplement question would be useful. Participants in round two were asked to rate a vitamin D supplementation question; the mean was 3.93 (SD 2.09), thus indicating a

somewhat necessary addition to SCREEN. Continuing the survey, there were two questions presented to the experts on the format of supplementation. One question had the option for a specific dosage of either calcium or vitamin D supplementation, while the second question focused on simply asking use of a supplement of vitamin D or calcium. A simple question to ask older adults on their supplementation was ranked as most appropriate (**Table 4**). (Do you take a supplement; yes, no, not sure).

Table 4 Supplement Rating Questions (n=15)

Questions		Preference
Please identify the one you prefer in the box below and suggest any changes in wording.	A) If you take a daily supplement with vitamin D, what is the dose?	4 (26.7%)
	4 ☐ more than 1000IU.	
	3 ☐ 1000IU.	
	2 ☐ 400- 999IU	
	1 ☐ less than 400IU	
	0 ☐ do not take a vitamin D supplement	
	B) Do you take a Vitamin D supplement?	10 (66.7%)
	4 ☐ Yes.	
	1 ☐ Not sure.	
	0 ☐ No.	
	Prefer not to answer	1 (6.7%)
Please identify the one you prefer in the box below and suggest any changes in wording.	A) If you take a daily supplement with calcium, what is the dose?	3 (20%)
	4 ☐ more than 800 mg	
	3 ☐ 501- 799 mg 2 ☐ 250- 500 mg	
	1 ☐ less than 250 mg	
	0 ☐ do not take a supplement with calcium	
	B) Do you take a calcium supplement?	9 (60%)
	4 ☐ Yes.	
	1 ☐ Not sure.	
	0 ☐ No.	
	Prefer not to answer	3 (20%)

4.5 Discussion

SCREEN-14 is rated relatively high as a tool that could identify nutrition risk in older adults who are frail. After two rounds of a Delphi, a potential new version of SCREEN that can be used specifically for frail older adults has been created through expert consensus. This version of SCREEN (SCREEN-Frail) has eight questions, similar to SCREEN-8, an already existing brief version of SCREEN. However, SCREEN-Frail focuses more on questions about protein, calcium, and vitamin D consumption, consistent with the literature on key nutrients of focus for individuals with frailty (Bucheber et al., 2019; Coelho-Junior et al., 2020; Coelho-Junior et al., 2022; Hernández Morante et al., 2019; Landi et al., 2016; Ni Lochlainn et al., 2021; Prado et al., 2022). In the first round there were two questions that asked experts to indicate the necessity of SCREEN-14 questions and the questions' ability to trigger risk in a frail older adult. There were similar results from both questions, with 80% consensus on what items to include in SCREEN-Frail which were confirmed in the second round. However, consensus on what items to exclude was only achieved for two items. Considered with the rating for the full SCREEN-14 assessing risk in frail older adults, the full version may be preferable for identifying risk in frail older adults.

Moving through the two rounds of the Delphi there were some thoughts on adding additional questions on supplementation. In round one, experts felt that the SCREEN questions around protein and calcium were adequate for a frail older adult,

but that items did not do a good job of reflecting vitamin D. It was noted in comments that a majority of older adults are likely to be taking a vitamin D supplement and some suggested asking about supplementation in SCREEN-Frail. With this in mind, supplementation questions were asked in the second round to gather experts' opinion on including a question or two in the final set. However, there was a lack of consensus on adding a calcium or vitamin D question to SCREEN-Frail.

Overall, the results of the Delphi provide content validity for a new SCREEN-Frail version to be further tested in older adults in the community who are potentially frail. The scoring and cut-point for risk of SCREEN-Frail is suggested to be the same as SCREEN-8; SCREEN-Frail includes the same four questions as SCREEN-8 that are double-weighted. To be consistent with SCREEN-8, SCREEN-Frail could have a cut-point of <38 in the doubled weighted version. For an unweighted version it can be suggested that the cut-point be ≤ 22 . To further validate SCREEN-Frail, the eight questions selected for inclusion would need to be tested in a frail population to indicate whether it can identify nutrition risk in this population as compared to SCREEN-8. Criterion validation when using the semi-gold standard of the dietitian's clinical frailty scale score should also be pursued if SCREEN-Frail is to be used in clinical practice and research.

4.5.1 Strengths

This study has several strengths, the first being that the Delphi method can determine content validity based on the judgement of experts (Fink-Hafner et al., 2019). This study had a sample that is considered sufficient for a Delphi method (Diamond et al., 2014; Gattrell et al., 2022; Vogel et al., 2019), and diverse geographic representation beyond Canada was achieved due to the use of an online survey, which could be completed at the participant's convenience. The lack of face-to-face interaction also allowed for anonymity, thus encouraging creativity, honesty, and a balanced consideration of ideas while reducing the risk of group dynamics (Fink-Hafner et al., 2019). Noisy data happens more often in focus groups, whereas a Delphi reduces this chance (Hsu & Sandford, 2019). Another strength to this Delphi was the short turnaround time between the two rounds, keeping participants interested and more likely to complete the different rounds (Keller et al., 2015). Finally, although there was some overlap between the two rounds, new participants in round two provided further confidence in the identification of potential items to include in SCREEN-Frail.

4.5.2 Limitations

The first and probably the biggest limitation is the way the participants were invited to join the study. It is common that the experts will be identified through a pre-existing network of collaborators and those with shared interest in the topic or tool in this

case (Savic & Smith, 2022). This then leaves the possibility of sharing the same views as the principal investigator. All but one of the participants had used SCREEN in a professional or research capacity. The experts recruited to participate in this Delphi study were gathered from a contact list of the creator (H. Keller) of SCREEN. This promoted efficiency in participant recruitment but may have introduced bias. To mitigate this bias, the research assistant was the only person extending invitations for the second round, addressing any queries by participants, and reviewing the individual responses and amalgamating them for co-authors to review. The sample size is a limitation as well, although literature suggests that twelve is the minimum number of experts, which was met, there is a benefit to a larger sample size (Chalmers & Armour, 2019; Vogel et al., 2019). Increasing the sample size and diversity of participants in this study would improve the strength of the content validity. The way participants were gathered could have also been improved. Gathering experts in a different way could have been beneficial such as asking dietitians or people in the field of older adult nutrition their thoughts on the SCREEN tool. This would have helped increase sample size and reduce the potential bias of experts who had used the tool for research rather than practice. It also would have helped gather a more diverse population rather than mostly white females. Having a more diverse population from different parts of the world could have improved the quality of the results and benefits of this screening tool could reach a larger population (Shea et al., 2022). Another aspect of the study that could be

improved would be including the definition of frailty in the Delphi survey. Although the definition of frailty has been changing and there is no consensus, providing a definition would have helped frame the scope of this study. This would then have eliminated any concern if the participants had a different view of frailty, and it would have helped keep the study within the scope of our definition of frailty. Another limitation is that the results are based on the opinion of experts in the older adult nutrition community and not on primary data (Fink-Hafner et al., 2019). This is a fundamental limitation of a Delphi study (Hus & Sandford 2019), and although the results are based on opinion, it lays the groundwork for future studies to be conducted on the validity and reliability of a new version of SCREEN.

4.6 Conclusion

This study sought to achieve consensus on a new version of SCREEN through expert opinion using a Delphi method. The experts reached consensus on eight questions that were deemed the ‘most appropriate’ questions to ask a frail older adult who is at risk for poor nutrition. The questions included items that tap into protein and calcium intake, nutrients considered important in delaying the progression of frailty (Buchebner et al., 2019; Coelho-Junior et al., 2020; Coelho-Junior et al., 2022; ; Hernández Morante et al., 2019; Landi et al., 2016; Ni Lochlainn et al., 2021; Prado et al., 2022). As the older adult population continues to grow, future research should aim to improve screening tools to include more at-risk populations such as those over the

age of 75, who are more likely to be at risk for frailty (Lang et al., 2009; Pérez-Ros et al., 2020; Rockwood & Mitnitski, 2007). SCREEN-Frail requires further testing by comparing to other abbreviated versions of SCREEN, as well as testing for criterion validity using a semi-gold standard such as the dietitian's clinical frailty scale score.

4.7 References

- AlMohaisen, N., Gittins, M., Todd, C., & Burden, S. (2022). What is the overlap between malnutrition, frailty and sarcopenia in the older population? study protocol for cross-sectional study using UK Biobank. *PLOS ONE*, 17(12). <https://doi.org/10.1371/journal.pone.0278371>
- Barrett, D., & Heale, R. (2020). What are Delphi Studies? *Evidence Based Nursing*, 23(3), 68–69. <https://doi.org/10.1136/ebnurs-2020-103303>
- Bloom, I., Zhang, J., Parsons, C., Bevilacqua, G., Dennison, E. M., Cooper, C., & Ward, K. A. (2022). Nutritional risk and its relationship with physical function in community-dwelling older adults. *Aging Clinical and Experimental Research*, 34(9), 2031–2039. <https://doi.org/10.1007/s40520-022-02171-3>
- Borkent, J. W., Schuurman, L. T., Beelen, J., Linschooten, J. O., Keller, H. H., Roodenburg, A. J. C., & De van der Schueren, M. A. E. (2020). What do screening tools measure? lessons learned from screen II and snaq65+. *Clinical Nutrition ESPEN*, 38, 172–177. <https://doi.org/10.1016/j.clnesp.2020.05.008>
- Borkent, J., Naumann, E., Vasse, E., van der Heijden, E., & De van der Schueren, M. (2019). Sun-PO238: Prevalence and determinants of undernutrition in a sample of Dutch community-dwelling older adults: Results from two online screening tools. *Clinical Nutrition*, 38. [https://doi.org/10.1016/s0261-5614\(19\)32870-5](https://doi.org/10.1016/s0261-5614(19)32870-5)
- Buchebner, D., Bartosch, P., Malmgren, L., McGuigan, F. E., Gerdhem, P., & Akesson, K. E. (2019). Association Between Vitamin D, Frailty, and Progression of Frailty in Community-Dwelling Older Women. *The Journal of Clinical Endocrinology & Metabolism*, 104(12), 6139–6147. <https://doi.org/10.1210/jc.2019-00573>
- Buhl, S. F., Beck, A. M., Olsen, P. Ø., Kock, G., Christensen, B., Wegner, M., Vaarst, J., & Caserotti, P. (2022). Relationship between physical frailty, nutritional risk factors and protein intake in community-dwelling older adults. *Clinical Nutrition ESPEN*, 49, 449458. <https://doi.org/10.1016/j.clnesp.2022.03.004>

- Cederholm, T., Barazzoni, R., Austin, P., Ballmer, P., Biolo, G., Bischoff, S. C., Compher, C., Correia, I., Higashiguchi, T., Holst, M., Jensen, G. L., Malone, A., Muscaritoli, M., Nyulasi, I., Pirlich, M., Rothenberg, E., Schindler, K., Schneider, S. M., de van der Schueren, M. A. E., ... Singer, P. (2016). Espen guidelines on definitions and terminology of Clinical Nutrition. *Clinical Nutrition*, 36(1), 49–64. <https://doi.org/10.1016/j.clnu.2016.09.004>
- Chalmers, J., & Armour, M. (2019). The delphi technique. *Handbook of Research Methods in Health Social Sciences*, 715–735. https://doi.org/10.1007/978-981-10-5251-4_99
- Coelho-Junior, Hélio J., Marzetti, E., Picca, A., Cesari, M., Uchida, M. C., & Calvani, R. (2020). Protein intake and frailty: A matter of quantity, quality, and timing. *Nutrients*, 12(10), 2915. <https://doi.org/10.3390/nu12102915>
- Coelho-Junior, Hélio José, Calvani, R., Picca, A., Tosato, M., Landi, F., & Marzetti, E. (2022). Protein intake and frailty in older adults: A systematic review and meta-analysis of observational studies. *Nutrients*, 14(13), 2767. <https://doi.org/10.3390/nu14132767>
- Diamond, I. R., Grant, R. C., Feldman, B. M., Pencharz, P. B., Ling, S. C., Moore, A. M., & Wales, P. W. (2014). Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi Studies. *Journal of Clinical Epidemiology*, 67(4), 401–409. <https://doi.org/10.1016/j.jclinepi.2013.12.002>
- Fink-Hafner, D., Dagen, T., Doušak, M., Novak, M., & Hafner-Fink, M. (2019). Delphi method: Strengths and Weaknesses . *Advances in Methodology and Statistics*, 16(2). <https://doi.org/10.51936/fcfm6982>
- Gattrell, W. T., Hungin, A. P., Price, A., Winchester, C. C., Tovey, D., Hughes, E. L., van Zuuren, E. J., Goldman, K., Logullo, P., Matheis, R., & Harrison, N. (2022). Accord guideline for reporting consensus-based methods in biomedical research and clinical practice: A study protocol. *Research Integrity and Peer Review*, 7(1). <https://doi.org/10.1186/s41073-022-00122-0>
- Hernández Morante, J. J., Gómez Martínez, C., & Morillas-Ruiz, J. M. (2019). Dietary factors associated with frailty in old adults: A review of nutritional interventions to prevent frailty development. *Nutrients*, 11(1), 102. <https://doi.org/10.3390/nu11010102>

- Hsu, Chia-Chien and Sandford, Brian A. (2019) "The Delphi Technique: Making Sense of Consensus," *Practical Assessment, Research, and Evaluation*: Vol. 12, Article 10. <https://doi.org/10.7275/pdz9-th90>
- Keller, H H, Goy, R., & Kane, S.-L. (2005). Validity and reliability of screen II (seniors in the community: Risk evaluation for eating and nutrition, version II). *European Journal of Clinical Nutrition*, 59(10), 1149–1157. <https://doi.org/10.1038/sj.ejcn.1602225>
- Keller, H. H., & Trinca, V. (2023). Determinants of a decline in a nutrition risk measure differ by Baseline High Nutrition Risk Status: Targeting nutrition risk screening for frailty prevention in the Canadian Longitudinal Study on Aging (CLSA). *Canadian Journal of Public Health*, 114(4), 593–612. <https://doi.org/10.17269/s41997-023-00745-w>
- Keller, H. H., McCullough, J., Davidson, B., Vesnaver, E., Laporte, M., Gramlich, L., Allard, J., Bernier, P., Duerksen, D., & Jeejeebhoy, K. (2015). The Integrated Nutrition Pathway for Acute Care (INPAC): Building consensus with a modified Delphi. *Nutrition Journal*, 14(1). <https://doi.org/10.1186/s12937-015-0051-y>
- Keller, H. H., Ostbye, T., & Goy, R. (2004). Nutritional risk predicts quality of life in elderly community-living Canadians. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 59(1). <https://doi.org/10.1093/gerona/59.1.m68>
- Landi, F., Calvani, R., Tosato, M., Martone, A., Ortolani, E., Saveria, G., D'Angelo, E., Sisto, A., & Marzetti, E. (2016). Protein intake and muscle health in old age: From biological plausibility to clinical evidence. *Nutrients*, 8(5), 295. <https://doi.org/10.3390/nu8050295>
- Lang, P.-O., Michel, J.-P., & Zekry, D. (2009). Frailty syndrome: A transitional state in a dynamic process. *Gerontology*, 55(5), 539–549. <https://doi.org/10.1159/000211949>
- Laur, C., & Keller, H. (2017). Making the case for nutrition screening in older adults in primary care. *Nutrition Today*, 52(3), 129–136. <https://doi.org/10.1097/nt.0000000000000218>
- Morrison, J. M., Laur, C. V., & Keller, H. H. (2019). Screen III: Working towards a condensed screening tool to detect nutrition risk in community-dwelling older adults using CLSA data. *European Journal of Clinical Nutrition*, 73(9), 1260–1269. <https://doi.org/10.1038/s41430-019-0411-3>

Nasa, P., Jain, R., & Juneja, D. (2021). Delphi methodology in healthcare research: How to decide its appropriateness. *World Journal of Methodology*, 11(4), 116–129.
<https://doi.org/10.5662/wjm.v11.i4.116>

Ni Lochlainn, M., Cox, N. J., Wilson, T., Hayhoe, R. P., Ramsay, S. E., Granic, A., Isanejad, M., Roberts, H. C., Wilson, D., Welch, C., Hurst, C., Atkins, J. L., Mendonça, N., Horner, K., Tuttiett, E. R., Morgan, Y., Heslop, P., Williams, E. A., Steves, C. J., ... Robinson, S. (2021). Nutrition and frailty: Opportunities for prevention and treatment. *Nutrients*, 13(7), 2349.
<https://doi.org/10.3390/nu13072349>

Niederberger, M., & Spranger, J. (2020). Delphi technique in Health Sciences: A Map. *Frontiers in Public Health*, 8. <https://doi.org/10.3389/fpubh.2020.00457>

Pavlović, J. R., Maksimović, M., Klopunović, O. V., Vasilić, Z. S., Ivković, N. M., & Račić, M. N. (2020). Comparison of seniors in the community: Risk evaluation for eating and nutrition, version II and Mini Nutritional Assessment – short form in detecting nutritional risk among community-dwelling seniors in Bosnia and Herzegovina. *Public Health Nutrition*, 24(9), 2681–2688.
<https://doi.org/10.1017/s1368980020002438>

Pérez-Ros, P., Vila-Candel, R., & Martínez-Arnau, F. M. (2020). A home-based exercise program focused on proprioception to reduce falls in frail and pre-frail community-dwelling older adults. *Geriatric Nursing*, 41(4), 436–444. <https://doi.org/10.1016/j.gerinurse.2020.01.017>

Prado, C. M., Landi, F., Chew, S. T. H., Atherton, P. J., Molinger, J., Ruck, T., & Gonzalez, M. C. (2022). Advances in muscle health and nutrition: A toolkit for healthcare professionals. *Clinical Nutrition*, 41(10), 2244–2263. <https://doi.org/10.1016/j.clnu.2022.07.041>

Qualtrics. (2023). Qualtrics XM [Computer software]. Provo, UT: Qualtrics, LLC. Available from <https://www.qualtrics.com>

Rockwood, K., & Mitnitski, A. (2007). Frailty in relation to the accumulation of deficits. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 62(7), 722–727.
<https://doi.org/10.1093/gerona/62.7.722>

Santaguida, P., Dolovich, L., Oliver, D., Lamarche, L., Gilsing, A., Griffith, L. E., Richardson, J., Mangin, D., Kastner, M., & Raina, P. (2018). Protocol for a Delphi consensus exercise to identify a core set of criteria for selecting health related outcome measures (HROM) to be used in primary health care. *BMC Family Practice*, 19(1). <https://doi.org/10.1186/s12875-018-0831-5>

Savic, L. C., & Smith, A. F. (2022). How to conduct a Delphi Consensus process. *Anaesthesia*, 78(2), 247–250. <https://doi.org/10.1111/anae.15808>

Shea, L., Pesa, J., Geonnotti, G., Powell, V., Kahn, C., & Peters, W. (2022). Improving diversity in study participation: Patient perspectives on barriers, racial differences and the role of Communities. *Health Expectations*, 25(4), 1979–1987. <https://doi.org/10.1111/hex.13554>

Valentini, A., Federici, M., Cianfarani, M. A., Tarantino, U., & Bertoli, A. (2018). Frailty and nutritional status in older people: The Mini Nutritional Assessment as a screening tool for the identification of frail subjects. *Clinical Interventions in Aging*, Volume 13, 1237–1244. <https://doi.org/10.2147/cia.s164174>

Vogel, C., Zwolinsky, S., Griffiths, C., Hobbs, M., Henderson, E., & Wilkins, E. (2019). A Delphi Study to build consensus on the definition and use of big data in Obesity Research. *International Journal of Obesity*, 43(12), 2573–2586. <https://doi.org/10.1038/s41366-018-0313-9>

CHAPTER 5: CREATING AN ALTERNATIVE BRIEF SCREEN USING NUTRI-ESCREEN

Target Journal: undecided

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5.1 Overview

Background

Screening for nutrition risk in the community is increasing. As there are barriers such as lack of time to screening in clinical settings, there is a need for brief nutrition risk screening tools.

Objective

This research aimed to use item-level parameters returned by Item Response Theory (IRT), specifically using the Graded Response Model (GRM), to inform the selection of items included in a brief version of SCREEN-14. Additionally, the overlap of risk between three versions of SCREEN (SCREEN-8, SCREEN-Frail, and SCREEN-IRT) was determined.

Participants

Users who visited the Nutri-eSCREEN website between December 2011 to August 2020 were included. After applying exclusions, 20,093 participants remained.

Statistical analyses

The GRM was used to return item-parameter estimates for items in SCREEN-14. A KW-ANOVA was performed between SCREEN-14 and demographic characteristics of users

to evaluate the variance ($p < 0.0001$). The 'best', items were then re-analyzed for assessment of unidimensionality. A kappa statistic was performed to determine overlap in three brief versions of SCREEN. The cut-point deemed as 'at risk' for this comparison was ≤ 22 .

Results

Eight questions were selected for inclusion by IRT. With SCREEN-8, 42.1% were 'at risk'. SCREEN-Frail, 33.6% at risk and SCREEN-IRT, 27.7%. The overlap of participants identified as at risk by all three was 77.4%. Items in the SCREEN-IRT demonstrate high item-information at the lower end of nutrition risk, a high standard error at the higher end of nutrition risk and demonstrate good model fit (RMSEA 0.075; CFI 0.905). SCREEN-8 also demonstrates a good/acceptable model fit (RMSEA 0.064; CFI 0.913) while SCREEN-Frail demonstrates a mediocre model of fit (RMSEA = 0.082; CFI 0.882).

Conclusions

A new 8-item version of SCREEN was created with IRT. This tool has different items than SCREEN-8 and SCREEN-Frail and appears to underestimate risk in comparison. Model fit was good and similar to SCREEN-8. Further research on criterion validity of SCREEN-IRT is needed.

5.2 Introduction

The older adult population of Canada is on a steady incline; it is expected that 21 to 29% of the Canadian population will be over the age of 65 by 2068 (Statistics Canada, 2022). As compared to the growth rate of the overall older adult population, those in the subset category of 75 years and older are growing at a faster rate than the rest of the population (Canadian Institute for Health Information, 2017). As adults get older there is an increased risk of becoming frail as well as an increased risk for other health ailments such as poor nutrition, lower mobility, and impairments of daily activities (Corral-Pérez et al., 2023; Volker et al., 2019). Frailty can be defined as a progressive age-related decline characterized by vulnerability to adverse health outcomes (Fried et al., 2001; Walston et al., 2018). Despite frailty being a potentially progressive condition, there are ways to reverse or slow the trajectory, one of which is through improving nutritional status (Wang et al., 2022). Nutrition risk and inadequate food intake are key determinants of frailty (Lorenzo-López et al., 2017). The first step to improving nutrition risk is through screening to know if an older adult is at risk. Valid and reliable screening tools in the community-dwelling older adult population are needed for this first step.

A screening tool that is appropriate for community-living seniors and screening for nutrition risk in potentially frail older adults is SCREEN-14 (Seniors in the Community: Risk Evaluation for Eating and Nutrition). This tool has gone through construct and criterion validity testing in community-dwelling older adults (Keller et al.,

2005). SCREEN is a 17-item questionnaire with three main attributes of nutritional risk of weight change (increase or decrease), food intake, and risk factors associated with food intake (Keller et al., 2005; Keller et al., 2000). The cut-point for risk is <50 . As there was a concern that SCREEN-14 was too long for clinical practice, during the initial validity and reliability testing of SCREEN-14, an abbreviated version was also developed and tested. This shorter version was developed with the expertise of dietitians rating the best questions to include, as well as those that were essential which became double-weighted questions in SCREEN-8: self-reported weight change, appetite, skipping meals, and having difficulty swallowing (Keller et al., 2005). SCREEN-8 has also gone through validity testing as compared to the criterion of a dietitian risk rating and a cut-point of <38 was chosen for determining risk with the best combination of sensitivity and specificity (Keller et al., 2005). Another version of SCREEN was more recently created through a Delphi method (**Chapter 4**) with expert consensus on the best questions in SCREEN to ask potentially frail older adults; as only one item on SCREEN-8 is a food intake item, it was wondered if other items might better reflect the nutrition risk of a frail group. This version also has eight questions and the four double-weighted questions in SCREEN-8 overlap with this newer version. The new version is named SCREEN-Frail and the same cut-point as SCREEN-8 has been suggested due its consistent length and use of double-weighted questions.

Since SCREEN's original creation, there has been an upswing of online platforms for the intended use of providing health information and self-management. Research shows that there is a growing acceptance of information and communication through technology in the older adult population (Anderson & Perrin, 2017). The creation of Nutri-eSCREEN was intended to give older adults a credible source of information for individualized nutrition-related education, promoting awareness and improving knowledge about nutrition (Keller, 2016). The online platform of Nutri-eSCREEN was originally created in 2012 containing SCREEN II (now known as SCREEN-14) along with resources for adults aged 50+ to self-manage their nutrition risk in an upstream manner (Keller, 2016). However, this tool was not specific to those older adults who may be most at risk for poor nutrition and need for services.

Some of the patterns that came out of the analysis in this original paper was that as a user became older, mean SCREEN scores decreased, with the age group with the lowest score being over 85 years; 68% of those in the age 85+ age group were identified to be at high risk for poor nutrition as compared to 37% in those in the 50-64 age group (Keller, 2016). There were also several age differences that were statistically significant especially with the older age group (85+) compared to the younger age groups, such as perception of weight; normally selecting underweight or 'just right' whereas the younger group had the perception of being overweight or trying to change their weight (Keller, 2016). These patterns show that as adults get older, they are

reporting increasing nutrition challenges and have different risk behaviours with age. Specifically, as the participant reported an older age, they were more likely to skip meals, eat alone, and have cooking and shopping difficulties as compared to the younger age groups (Keller, 2016). Poor appetite and chewing and swallowing difficulties were also more common in the older age groups than the younger (Keller, 2016). These findings suggest that if a shorter version of SCREEN is needed, one that specifically focuses on those most in need of services, who are potentially frail, may be a way to target screening in primary care clinics. With the large sample involved in Nutri-eSCREEN which includes the full SCREEN tool, there is the opportunity to identify a subset of questions that are most relevant for determining nutrition risk in potentially frail older adults in the community. The Nutri-eSCREEN data base was voluntarily completed by older adults in the community and includes age and sex as well as all the SCREEN questions, providing an opportunity for psychometric analysis in a large sample, as well as construct validity.

5.3 Introduction to Item Response Theory

A brief version of SCREEN is desired for improving implementation and response and completion rates (Kost & Correa de Rosa, 2018). SCREEN-8 was developed out of the need for a short tool both in clinical practice, as well as for surveillance with national surveys. When measures are shortened, while still ensuring that the overall concept of

nutrition risk is still being captured, they are highly beneficial in research and clinical settings (Kost & Correa de Rosa, 2018). A model that aids in shortening a measure is the Polytomous Rasch Model which is a psychometric approach to the Item Response Theory (Ostini & Nering, 2006). The Item Repose Theory (IRT) in the past has been used to improve the development, refinement, and evaluation of patient reported outcome measures such as surveys and questionnaires (Nguyen et al., 2014). In other words, it is an approach used to abbreviate measures, to get the best possible questions or items. The IRT can model the relationship of the individual items on the questionnaire to the overall concept being measured (Nguyen et al., 2014). In this study, the individual items are the questions on the SCREEN tool and the concept is nutrition risk. The IRT is essentially a set of mathematical models that describe the relationship between an individual's 'ability' or 'trait' and how they respond to items on a scale (Hays et al., 2000; Reise et al., 1993). The IRT focuses on the item level data and modeling, by using item level characteristics that allow for the identification and selection of items that differentiate across levels of a construct (nutrition risk) (Stenbeck et al., 1992). Within the set of mathematical models for IRT, there are a few separate models that can be used to differentiate items and their response within a construct. The model that is being used for this analysis is the Graded Response Model (GRM). The GRM is appropriate to use when response options to items are ordered categories on a rating scale (Zanon et al., 2016). In the case of SCREEN, there are ordered

categories of high risk and low risk depending on the response option for each SCREEN-14 question. In this model, there are a few major components to help decide on the best subset of items or questions. One of these is the graphical representation of the probability of a person responding to a specific category in the item being examined (Xie, 2017). This graphical representation is known as Item Response Category Characteristic Curves (IRCCC). IRCCC are curves that represent the probability of endorsing a response category within an item or question. These IRCCC also have a relationship with theta (θ); as theta increases, the probability of endorsing a category increases for those with the trait (e.g. nutrition risk) and then decreases as the responses transition to the next higher category (Xie, 2017). Through an analysis of different item characteristics, the IRT can guide the decision processes to help find the best questions for an abbreviated version of SCREEN.

The objectives of this study were to: 1a) create an abbreviated version of SCREEN-14 using the GRM of the IRT, 1b) determine if the abbreviated set is different if only those 75+ years of age (potentially frail group) are included in the analysis, 2) determine what the differences are by age and sex for each item on SCREEN-14 to provide construct validity for items included in the abbreviated version, and finally 3) compare model fit and evaluate the overlap in identification of nutrition risk between the new SCREEN versions (SCREEN-Frail, SCREEN-IRT) and SCREEN-8.

5.4 Methods

5.4.1 Participants

The data used in this secondary analysis was collected from users who completed the Nutri-eSCREEN on the website from December 2011 until August 2020. Information that was collected was the participant's age, sex, postal code, country, province, region, frequency of visits to the website, and their referral source to the website. In the dataset there is a total of 40,758 participants. The inclusion criteria for this analysis were: users over the age of 50, participants who completed the full survey (e.g. answered all SCREEN questions), who were first time visitors of the Nutri-eSCREEN website, and Canadian users to limit potential language barriers. After applying these exclusions there was 20,093 participants for this analysis. This sample size is sufficient in providing accurate results in the IRT models (Jiang et al., 2016). Having more participants per item in an IRT analysis is beneficial as it can improve the estimation accuracy of item parameters leading to more reliable results (Jiang et al., 2016). Ethics for secondary analysis of this data set was obtained from the University of Waterloo Office of Research Ethics (ORE #42476).

5.4.2 Instrument

The Nutri-eSCREEN was a self-reported online nutrition risk screening tool for older adults in the community (Keller et al., 2000). This online version used the full

SCREEN-14 version with the highest potential score being 64 and the lowest being 0. Persons with higher scores have a low nutrition risk and persons with lower scores (< 50) are considered “high risk” for poor nutrition. Scoring “high risk” with SCREEN is associated with poor health outcomes (Keller et al., 2000; Keller & Trinca, 2023). This tool has seventeen items with responses ranging from 0 – high nutrition risk to 4 – low risk (or 8 for double-weighted items in the abbreviated SCREEN-8).

5.4.3 Descriptive Analysis

The purpose of the descriptive analysis was to determine the participants’ differences in their nutrition risk behaviours (i.e. each SCREEN item) by age and sex, as well as determination of mean scores and risk by total sample and by age and sex. Frequency and mean (+ / SD) are noted. Associations between SCREEN-14 items and demographic characteristics of users were completed using a Kruskal Wallis ANOVA to evaluate whether there are statistically significant differences in the distribution of scores among sex and age groups separately. All analyses were completed using the statistical software RStudio Team (2024). RStudio: Integrated Development for R.

5.4.4 Identifying patterns in IRT

The data from Nutri-eSCREEN was cleaned in Microsoft Excel (Redmond, Washington, USA) and imported into R studio (Boston, Massachusetts, USA) for analysis. The data from the Nutri-eSCREEN dataset had to be split up between the item responses and the score for each SCREEN question. The reason for the division

between the SCREEN response options and the SCREEN scores is because in a polygamous IRT model, the focus is primarily on the characteristic of the items (question responses) rather than the scores of the individuals (Dodeen & Al-Darmaki, 2016). Hence, the need to divide the scores from the response options. Item probability functions were applied to estimate location parameters and discrimination statistics, from which IRCCC were produced to aid in decision making and interpretation. Items that showed high slopes correlated with item discrimination and were considered as candidates for the abbreviated version of the 'best' questions. The GRM analysis was repeated with only those over 75 years of age included (n=2,749) to determine if different questions would discriminate. Qualitative comparisons were made between the versions to see which items performed better, using the entire sample.

GRM analysis was performed on seventeen questions (full version of SCREEN). This model is used to provide the probability that the respondent must receive a specific score (high risk or the lower the score on the SCREEN item), given the underlying latent trait, which is nutrition risk. The more at risk for poor nutrition, the more likely they are to respond with options that are correlated with nutrition risk (Zanon et al., 2016). In the GRM, the probability (θ , theta), that a person's response falls at or above a particular ordered category given θ (level of latent trait) may be expressed as the parameter a which refers to the slope of item discrimination. This parameter is constant for all categories of the same item (Lubbe & Schuster, 2018). For example, in SCREEN the

slope for question 1a is the same across all response options. For each question graphically represented, there are three parameters that describe the curve, but for this study only two will be used. The first is the a parameter (slope), where the larger the a value (steeper slope) indicates that the item is more related to the trait (nutrition risk) and thus better for discriminating those who are at nutrition risk (Dodeen & Al-Darmaki, 2016). The second parameter is the b parameter (the threshold parameter) which is the location of the inflection point on the trait scale. In other words, this parameter represents the amount of the trait needed to have a 50% probability of endorsing the item. The larger the b , the more the trait is needed by a person to endorse the correct response category (Dodeen & Al-Darmaki, 2016). For example, in SCREEN-14, the skipping meals question, you would expect that a user who skips meals almost every day to be at a high risk for poor nutrition, therefore the b parameter should be large.

Once the abbreviated version was established, the shortened version was used to assess item and test information, standard error, predicted true score and model fit. The test-information function (TIF) is used to test the concept that people who have high nutrition risk are correctly picking the options that correlated with high nutrition risk. Essentially, the test-information is a graphical representation of precision and standard error (variability in estimation) across levels of nutrition risk (Raykov et al., 2019). There is no single statistic for the TIF; rather it is a function varying across the ranges of nutrition risk. The standard error is inversely related to the test information and

describes the degree of uncertainty associated with an individual's nutrition risk level estimate (Raykov et al., 2019). Additionally, the expected true score prediction curve is also computed to represent the relationship between an individual's observed score and their expected true score on SCREEN to measure nutrition risk (Raykov et al., 2019; Edelen & Reeve, 2007). Lastly, fitting statistics gauge how well the model can predict respondents' scores and generate item statistics that are constant over samples of respondents (Zanon et al., 2016). A strong fit between the model and the data indicates that the model accurately captures the relationship between item responses and the underlying trait (i.e., nutrition risk) (Hu & Bentler, 1999; Weston & Gore, 2006). In the assessment of model fit, it involves the investigation of disparities between the observed responses and those predicted by the model. In the assessment of model fit, there are a few statistics worth noting. The first statistic is the root mean square error of approximation (RMSEA), which assesses how far the hypothesized model is from a perfect model (Xia & Yang, 2019). The criterion for a good fit is <0.05 , an acceptable fit is between 0.05 and 0.08, a mediocre fit is between 0.08 and 0.10, lastly, a poor fit is >0.10 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). Similarly to the RMSEA, the Standardized root mean square residual (SRMSR) is also used to assess how well the model fits the data. The difference being the SRMSR measures the absolute measure of fit, meaning it assesses the fit of the model without considering model complexities. (Byrne, 1994). Due to the added complexities measured in

RMSEA, it is often prioritized while reporting the model of fit (Hu & Bentler, 1999). The criterion for a good fit is < 0.08 and a mediocre fit is < 0.10 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). On the flip side of RMSEA and SRMSR, the Tucker-Lewis Index (TLI) and the Comparative Fit Index (CFI) are incremental fit indices that compare the fit of a hypothesized model with a baseline model (Xia & Yang, 2019). Although the TLI and the CFI are very similar the key difference is that the CFI adjusts for sample size and is less affected by the model's complexity making it easier to interpret (Xia & Yang, 2019). Both the TLI and the CFI has the good fit threshold of > 0.90 and an excellent fit of > 0.95 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). It is important to include the fit indices as it provides a more well-rounded evaluation of model fit.

5.4.5 Coding for Risk Comparison Across Tools

The Nutri-eSCREEN dataset contains all seventeen questions from SCREEN-14. In addition to creating an abbreviated version of SCREEN, the secondary purpose was to find the overlap between this new version of SCREEN-IRT, SCREEN-Frail (**Chapter 4**) and SCREEN-8. In SCREEN-8 there are doubled weighted values for four questions deemed by experts and psychometric testing in its development to be the most important for nutrition risk (Keller et al., 2005). SCREEN-Frail also contains these four questions; therefore, they were also double weighted for scoring. The questions that are doubled weighted in SCREEN-8 are: has your weight changed in the past 6 months, do

you skip meals, how would you describe your appetite, and do you cough, choke, or have pain when swallowing food or fluids. SCREEN-8 uses a cut-point of < 38 to identify nutrition risk. As SCREEN-Frail contains the same double-weighted items, the same cut-point will be used. The derived IRT model from this analysis did not contain these same four double weighted questions but was eight items in length. To compare the three abbreviated tools, all questions were unweighted for scoring. We chose a cut-point of ≤ 22 to identify risk in these unweighted tools, as the highest score possible on the unweighted version is 32. This coincides with SCREEN-8 scoring where the 'at risk' cut-point is ten less than the highest possible score.

5.4.6 Comparison of Abbreviated Tools and Overlap of Risk

The newly created version of SCREEN-Frail (**Chapter 4**) and the SCREEN-IRT were compared to SCREEN-8. Specifically, the proportions identified at risk by each of the three versions of SCREEN were determined. Next the overlap of each version of SCREEN was determined. Those at risk were plotted as a Venn-Diagram and the overlap visually represented. Further, a kappa statistic was calculated to determine agreement on determination of risk/no risk for SCREEN-IRT and SCREEN-Frail in comparison to SCREEN-8. The kappa statistic is often used to test inter-rater reliability as it identifies agreement among categorical data (McHugh, 2012). Here we will use kappa to indicate the agreement between the various tools for identifying a participant

as 'at risk'. Fair agreement is identified as a Cohen Kappa result of 0.41-0.60, moderate as 0.61-0.80 and substantial as 0.81- 1.00 (McHugh, 2012).

5.5 Results

After excluding participants who did not meet the inclusion criteria, 20,093 people were included in the analysis. Descriptive results are provided in **Table 5**. Of these older adults, about 80% were female (69.3% age 75+) and the largest age group was 50-64 (59.3%). Finally, over 70% indicated they resided in Ontario.

Table 5 Characteristics of Nutri-eSCREEN users over the age of 50 years ($n= 20,093$)

Characteristic	n	% of Total
Sex		
Male	4060 (845 age 75+)	20.2 (30.7)
Female	16033 (1904 age 75+)	79.8 (69.3)
Age group (years)		
50-64	11915	59.3
65-74	5429	27.0
75-84	2130	10.6
85+	619	3.1
Region lives in, in Canada		
Ontario	14744	73.4
British Columbia	1566	7.8
Alberta	1067	5.3
Quebec	890	4.4
Other Canadian Provinces	1826	9.1

The mean Nutri-eSCREEN score was 45.1 (SD 8.4; range 0-64) with no statistically significant difference by sex. However, as the user became older, the mean score significantly decreased for each age group with those reporting being 85+ years of age having the lowest mean score of 36.9 (SD 12.3). Age and sex comparisons for each SCREEN-14 item embedded into Nutri-eSCREEN are provided in **Table 6**. Several age differences were statistically significant. For example, those aged 50-64 years were more likely to report a weight gain, whereas those over the age of 85 reported a weight loss in the prior six months ($X^2= 46.6$ $p < 0.0001$). Younger age groups were more likely to be trying to change their weight ($X^2= 369.3$ $p < 0.0001$) or thought they were too heavy ($X^2= 263.0$ $p < 0.0001$) as compared to older adults, who were more likely to see themselves as just right or underweight, especially those in the 85 and above age group. Unintentional weight change was reported at 32.3% in those over the age of 85 years. Key eating behaviours were different as well by age with older groups more likely to skip meals ($X^2= 53.6$ $p < 0.0001$), eat alone ($X^2= 334.8$ $p < 0.0001$), and having shopping for food difficulties ($X^2= 982.2$ $p < 0.0001$) than the younger age groups. Poor appetite ($X^2= 935.7$ $p < 0.0001$) and chewing ($X^2= 1291.4$ $p < 0.0001$) and swallowing difficulties ($X^2= 509.0$ $p < 0.0001$) were also common in older age groups. As expected, older age groups also had poorer consumption than younger age groups (fruit and vegetable: $X^2= 205.5$ $p < 0.0001$; meat and alternatives $X^2= 350.6$ $p < 0.0001$; fluid intake $X^2= 645.8$ $p < 0.0001$; meal replacement use $X^2= 298.2$ $p < 0.0001$). These age-

related differences help to identify construct validity of specific items that might be most relevant in an abbreviated SCREEN, if we consider advanced age (i.e., > 75 years) as a proxy for frailty.

No statistical differences in risk score were found by sex, however several individual items were statistically different. Notably, females compared to males were more likely to believe that they were too heavy ($X^2= 42.2$ $p < 0.0001$). However, males were more likely to skip meals than females ($X^2= 31.1$ $p < 0.0001$) and have poorer quality diet (fruit and vegetables $X^2= 209.6$ $p < 0.0001$; meat and alternatives $X^2= 43.8$ $p < 0.0001$; milk products $X^2= 72.8$ $p < 0.0001$; fluid intake $X^2= 46.0$ $p < 0.0001$). Males also reported more chewing difficulties than females ($X^2= 19.0$ $p < 0.0001$). Males were less involved in meal preparation ($X^2= 2323.9$ $p < 0.0001$) and reported meal preparation ($X^2= 434.8$ $p < 0.0001$) and grocery shopping difficulty ($X^2= 17.6$ $p < 0.0001$) less often than females.

Table 6 Proportions of Nutri-eSCREEN Items and Comparisons by Age and Sex (n= 20,093)

Item	Total	Male (n=4060)	Female (n=16033)	50-64 yrs (n=11915)	65-74 yrs (n=5429)	75-84 yrs (n=2130)	85+ yrs (n=619)
Proportion (%)							
Weight							
Gain 10+ pounds	9.0	7.2	9.5	10.6*	7.9	4.6	2.9
Gain 6-10	9.8	7.1	10.5	11.5	8.5	5.8	2.9
Gain 5	12.2	9.5	12.9	13.7	11.5	8.0	3.2
Stayed same	46.3	48.2	45.9	44.8	49.2	49.0	40.9
Lost 5	7.3	8.8	6.9	6.2	7.6	9.6	15.2
Lost 6-10	6.8	8.3	6.4	5.6	6.8	10.9	13.2
Lost 10+ pounds	6.6	8.7	6.1	5.8	6.6	8.9	16.3
Don't know weight	1.9	2.2	1.9	1.7	1.9	3.0	5.3
Trying to change weight							
Yes	47.9	41.0	49.6	52.8*	47.4	31.3	13.7
No	40.5	47.3	38.2	36.7	41.9	49.9	53.9
No but changed anyways	12.1	11.6	12.2	10.5	10.7	18.8	32.3
Weight perception							
More than want	71.3	63.9#	73.1	76.9*	72.1	50.1	28.1
Just right	21.2	24.9	20.2	18.6	21.0	31.5	35.7
Less than want	7.6	11.2	6.6	4.5	6.9	18.3	36.2
Skip meals							
Never/rarely	59.0	55.5#	59.9	59.6*	59.8	57.4	46.7
Sometimes	29.8	31.1	29.5	29.3	30.1	30.1	35.4
Often	5.9	7.5	5.5	5.9	5.3	6.8	8.2
Almost everyday	5.3	5.9	5.2	5.2	4.8	5.7	9.7
Limiting foods							
Eat most foods	47.3	46.9	47.5	47.0	47.8	49.3	42.3
Some/manage	37.2	39.5	36.7	37.2	37.6	36.8	36.3
Some/difficult	15.4	13.6	15.9	15.8	14.6	13.8	21.3
Appetite							
Very good	42.9	42.5	43.1	47.3*	41.7	29.5	15.7
Good	43.7	44.3	43.5	43.7	44.9	43.0	34.6
Fair	10.6	10.2	10.7	7.5	11.1	20.4	32.1
Poor	2.7	2.9	2.7	1.4	2.2	7.0	17.6
Fruit/ Vegetable							
5+ / day	30.6	24.5#	32.1	32.7*	30.7	23.1	15.7

4	23.3	20.5	24.0	23.5	22.9	24.1	19.2
3	23.2	24.1	22.9	22.2	23.9	25.8	25.8
2	13.8	17.5	12.8	12.8	13.9	16.6	21.1
<2/day	9.1	13.4	8.1	8.8	8.5	10.3	18.1
Meat/alternatives							
2+ per day	26.9	24.6#	27.6	30.8*	23.1	17.8	17.6
1-2	39.9	38.0	40.4	39.8	41.1	39.8	32.2
1	24.9	27.1	24.4	22.1	27.4	32.1	33.1
<1 per day	8.2	10.3	7.6	7.2	8.4	10.2	16.9
Milk products/alt							
3+ per day	11.2	10.6#	11.4	10.9	11.6	11.8	11.8
2-3	26.7	22.4	27.8	27.3	25.5	28.1	21.0
1-2	31.2	30.6	31.3	31.2	31.7	29.9	29.6
1	19.8	22.2	19.2	19.5	20.2	19.2	23.3
<1 per day	11.1	14.0	10.3	11.0	10.9	10.9	14.4
Fluid							
8+ cups/day	22.5	20.1#	23.1	26.4*	19.7	12.3	6.9
5-7	43.6	41.7	44.1	44.1	45.2	40.1	32.8
3-4	26.7	29.5	25.9	23.9	28.3	34.6	39.7
About 2	5.6	6.4	5.4	4.4	5.5	10.1	13.2
<2 cups/day	1.6	2.4	1.4	1.2	1.2	2.9	7.3
Swallowing difficulty							
Never	62.5	61.7	62.7	67.2*	60.4	48.6	38.7
Rarely	23.1	24.9	22.6	20.9	24.6	30.2	27.3
Sometimes	12.8	11.5	13.2	10.8	13.4	18.6	27.1
Often or always	1.5	1.8	1.4	1.0	1.5	2.6	6.8
Chewing difficulty							
Never	71.2	68.5#	71.9	77.7*	69.1	52.0	30.7
Rarely	16.7	18.2	16.3	14.3	17.4	25.4	25.5
Sometimes	10.2	10.1	10.2	7.1	11.4	18.8	30.9
Often or always	1.9	3.0	1.6	0.8	2.0	3.8	12.9
Use meal supplements							
Never or rarely	81.6	78.5#	82.4	83.7*	82.2	73.8	62.0
Sometimes	15.4	17.7	14.8	13.7	15.2	22.0	26.2
Often or always	2.9	3.8	2.8	2.5	2.6	4.2	11.8
Eat with others							
Never or rarely	15.9	15.5	15.3	11.9*	17.5	24.9	31.7
Sometimes	19.8	17.9	20.2	18.8	19.7	23.7	25.4
Often	16.7	18.7	16.2	19.5	13.1	11.5	12.4
Almost always	48.1	47.9	48.2	49.7	49.7	39.8	30.5
Who prepares meals							
They do	66.9	37.9#	74.2	67.1	69.3	64.3	50.4
They share	21.9	30.6	19.6	24.5	19.5	15.6	12.4

Someone else does	11.3	31.5	6.1	8.4	11.1	20.1	37.2
Meal preparation							
Enjoy	43.7	52.5#	42.0	45.1*	44.9	35.6	23.1
Sometimes a chore	40.1	33.1	41.4	39.9	39.6	41.8	44.5
Usually a chore	16.3	14.5	16.6	15.0	15.6	22.6	32.4
Satisfied with others cooking	84.7	91.0	76.4	85.7	90.1	82.9	69.1
Not satisfied with others cooking	15.3	9.0	23.6	14.3	9.9	17.1	30.9
Grocery difficulty							
Never or rarely	82.5	85.3#	82.3	87.2*	83.1	67.9	50.8
Sometimes	12.3	9.7	12.9	9.6	12.2	23.1	27.5
Often	3.1	3.2	3.0	2.0	3.1	6.1	11.6
Always	1.7	1.7	1.7	1.1	1.5	2.9	10.0
Total score							
Mean	45.1	44.9	45.1	45.9*	45.1	42.5	36.9
SD	8.4	8.4	8.3	7.6	8.1	10.0	12.3

#sex comparison statistically significant difference at $p < 0.0001$

*age comparison statistically significant difference at $p < 0.0001$

5.5.1 IRT Calibration and Item Selection

The criteria used to select the appropriate items for the shortened SCREEN-IRT version were slope (a) parameter, and the location parameter (b) and IRCCC. The values of the discriminating slope (a) parameter in **Table 7** range from -0.75 to 1.53, and the values in **Table 8** range from -0.61 to 2.15, which shows deviation in the discrimination values of the items for the entire sample (**Table 7**) and only those items identified in those over the age of 75 years (**Table 8**). For the first question in SCREEN-14, there are eight response options of weight change in the past six months. The parameter $b1$ represents the location where the probability exceeds 50% that the response is in the category 'gained more than 10 pounds' or in the category 'gained 6

to 10 pounds'. The parameter $b7$ therefore, represents the location where the probability exceeds 50% that the response is in the categories 'I don't know how much I weigh' or 'lost more than 10 pounds'. Considering the item slope (a) parameter, items with the highest slope values were identified.

Based on this concept, eight items (47%) of the scale for the whole sample was selected for more in-depth consideration. The slope for these items ranged from 0.75 to 1.53, thus indicating high discriminating values over the range of SCREEN-14. These items were 2, 4, 5, 6, 9, 10, and 14 (highlighted in **Table 7**). After reviewing the content of the items, it was concluded that it was important to include all of these since they capture the overarching concept of nutrition risk and there is no overlap among items. In the item response category characteristic curves, as the θ (theta) increases, the probability of endorsing a category increases and then decreases as the responses transition to the next ordered category. **Figure 1** shows the IRCCC for the eight 'best' items in the whole Nutri-eSCREEN sample. While **Figure 2** shows the IRCCC for the nine 'worst' items.

Table 7 Slope (a) Parameter and Location (b) parameter estimates for the 17 items in Nutri-eSCREEN for the total sample (n= 20,093)

No.	Item	<i>a</i>	<i>b1</i>	<i>b2</i>	<i>b3</i>	<i>b4</i>	<i>b5</i>	<i>b6</i>	<i>b7</i>
1a)	Weight change	0.18	-12.63	-8.03	-4.43	6.66	9.28	12.85	21.22
1b)	Weight change intention	0.41	-0.24	4.93	N/A	N/A	N/A	N/A	N/A
1c)	Perception of weight	0.46	2.02	5.59	N/A	N/A	N/A	N/A	N/A
2)	Skipping meals	1.33	0.35	2.02	2.74	N/A	N/A	N/A	N/A
3)	Food avoidance	0.30	-0.40	5.80	N/A	N/A	N/A	N/A	N/A
4)	Appetite	1.51	-0.30	1.66	3.10	N/A	N/A	N/A	N/A
5)	Vegetable and fruit intake	1.18	-0.88	0.16	1.28	2.39	N/A	N/A	N/A
6)	Protein intake	0.88	-1.32	0.91	3.11	N/A	N/A	N/A	N/A
7)	Milk and soy intake	0.54	-4.04	-0.99	1.59	4.08	N/A	N/A	N/A
8)	Fluid intake	0.72	-1.90	0.99	3.83	6.07	N/A	N/A	N/A
9)	Difficulty swallowing	0.75	0.74	2.60	5.93	N/A	N/A	N/A	N/A
10)	Difficulty chewing and biting	1.18	0.95	2.06	3.96	N/A	N/A	N/A	N/A
11)	Meal replacement use	0.66	2.44	5.57	N/A	N/A	N/A	N/A	N/A
12)	Eating with others	-0.75	2.53	0.92	-0.12	N/A	N/A	N/A	N/A
13a)	Who prepares the meals	0.01	51.50	151.27	N/A	N/A	N/A	N/A	N/A
13b)	Meal preparation	0.67	-0.13	2.87	N/A	N/A	N/A	N/A	N/A
14)	Ability to grocery shop	1.53	1.42	2.62	3.44	N/A	N/A	N/A	N/A

a represents the slope parameter (item discrimination), and *b1-b7* refers to the location parameter estimates

Figure 1 Item Response Category Characteristic Curves for ‘best’ eight questions in the Whole Sample

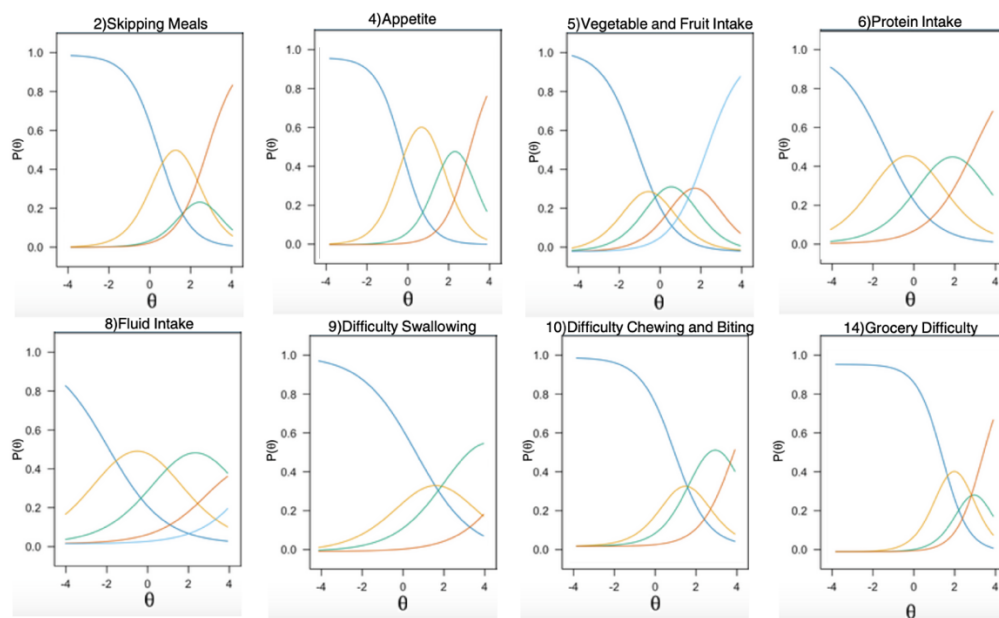
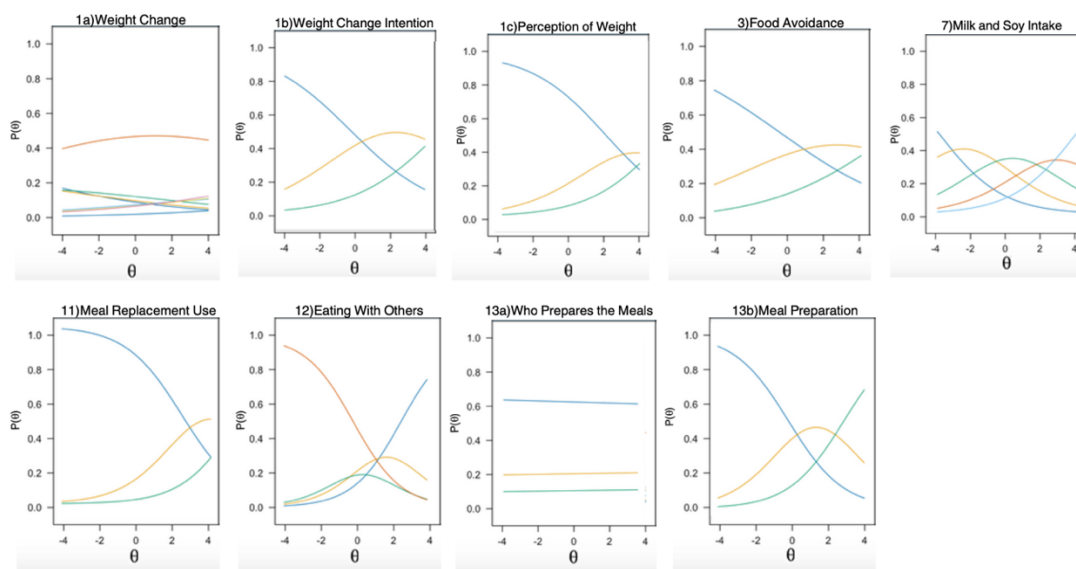


Figure 2 Item Response Category Characteristic Curves for ‘worst’ nine questions in the Whole Sample



When IRT analyses were re-run for only those participants in the data set over the of age 75, nine items (53%) were identified to have high slope parameters (*a*). Question 1c, the weight perception question (do you think your weight is...?) was excluded from further consideration as the other two weight-related questions were already included and would over-emphasize body weight in the final tool. Weight change, despite having a slightly lower slope, was chosen instead to move forward in an abbreviated tool as it is more useful in a clinical setting. Further, making a new questionnaire longer than SCREEN-8 was viewed as being disadvantageous for uptake and use of any new abbreviated tool. The slope for these items ranged from 0.97 to 2.15, indicating high discriminating values over the range of SCREEN-14 items, and better than those for the overall sample provided in Table 7. These items were 1a, 1b, 2, 4, 5, 8, 10, and 14 (indicated in bold in **Table 8**). In the IRCCC, as the θ (theta) increases, the probability of endorsing a category increase and then decreases as the responses transition to the next ordered category. **Figure 3** shows the item response category characteristic curves for the eight 'best' items in the in the 75+ Nutri-eSCREEN sample. While **Figure 4** shows the IRCCC for the nine 'worst' items.

Table 8 Slope (a) Parameter and Location (b) parameter estimates for the 17 items in Nutri-eSCREEN aged 75+ (n= 2,749)

No.	Item	<i>a</i>	<i>b1</i>	<i>b2</i>	<i>b3</i>	<i>b4</i>	<i>b5</i>	<i>b6</i>	<i>b7</i>
1a)	Weight change	0.97	-3.59	-2.70	-2.01	0.65	1.32	2.22	3.91
1b)	Weight change intention	1.00	-1.19	1.50	N/A	N/A	N/A	N/A	N/A
1c)	Perception of weight	1.11*	-0.27	1.35	N/A	N/A	N/A	N/A	N/A
2)	Skipping meals	1.34	0.18	1.81	2.53	N/A	N/A	N/A	N/A
3)	Food avoidance	0.73	-0.17	2.53	N/A	N/A	N/A	N/A	N/A
4)	Appetite	2.15	-0.84	0.55	1.75	N/A	N/A	N/A	N/A
5)	Vegetable and fruit intake	1.33	-1.28	-0.23	0.86	1.95	N/A	N/A	N/A
6)	Protein intake	0.88	-1.98	0.29	2.60	N/A	N/A	N/A	N/A
7)	Milk and soy intake	0.77	-2.88	-0.71	1.12	2.94	N/A	N/A	N/A
8)	Fluid intake	1.06	-2.32	-0.05	1.98	3.53	N/A	N/A	N/A
9)	Difficulty swallowing	0.86	-0.22	1.49	4.24	N/A	N/A	N/A	N/A
10)	Difficulty chewing and biting	1.27	-0.16	0.96	2.74	N/A	N/A	N/A	N/A
11)	Meal replacement use	0.79	1.27	3.85	N/A	N/A	N/A	N/A	N/A
12)	Eating with others	-0.61	1.82	0.00	-0.86	N/A	N/A	N/A	N/A
13a)	Who prepares the meals	0.11	3.98	10.17	N/A	N/A	N/A	N/A	N/A
13b)	Meal preparation	0.82	-0.36	2.03	N/A	N/A	N/A	N/A	N/A
14)	Ability to grocery shop	1.39	0.56	1.93	2.83	N/A	N/A	N/A	N/A

a represents the slope parameter (item discrimination), and *b1-b7* refers to the location parameter estimates

*not included in the final set despite higher slope value

Figure 3 Item Response Category Characteristic Curves for ‘best’ eight questions in the 75+ sample

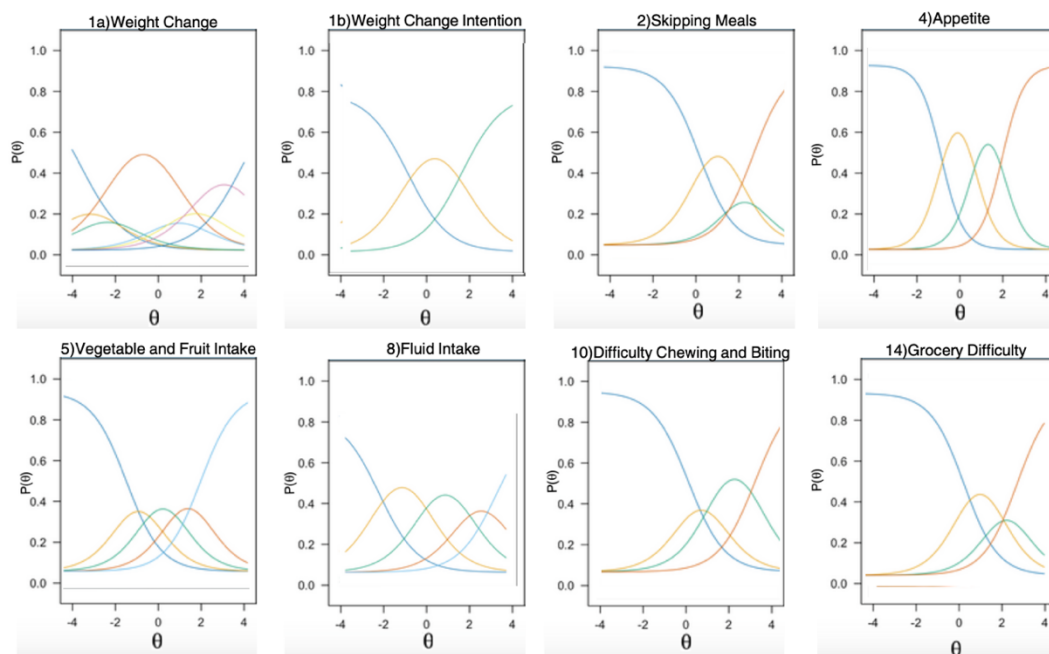
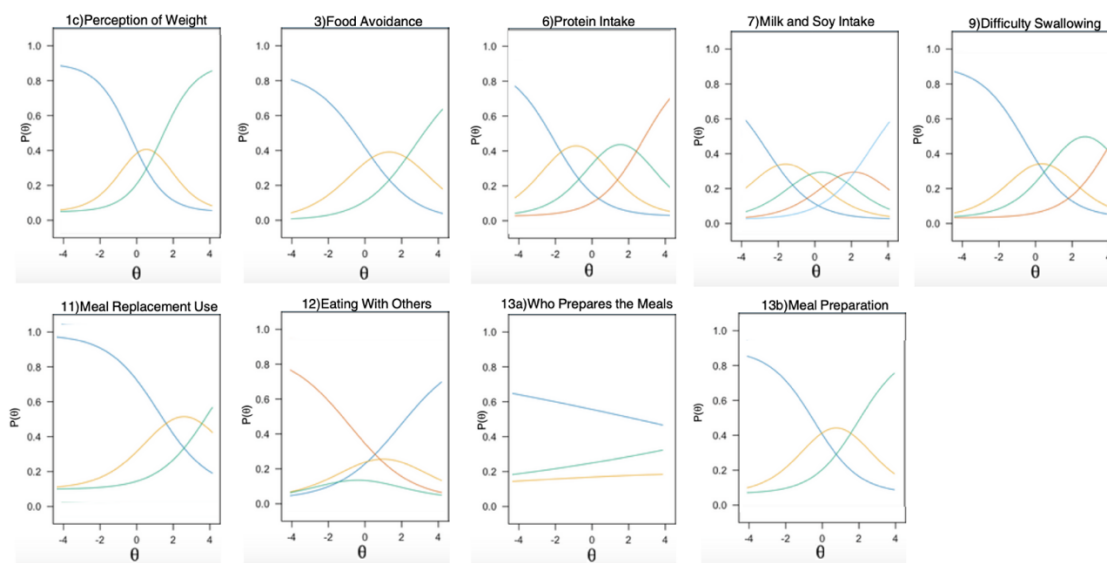


Figure 4 Item Response Category Characteristic Curves for ‘worst’ nine questions in the 75+ sample



When qualitatively comparing the two groups of IRT results, those based on all participants, and those based on just the sample over the age of 75 years, it was decided that the IRT 75+ group of questions were better for moving forward. This decision was based on two reasons. First, weight change is central to the concept of nutrition risk in older adults, and especially those who are frail. The IRT based on the whole sample did not result in the identification of any weight-related questions from SCREEN being selected as the best final set. Second, the graphical representation of the IRCCC showed that the items from the IRT 75+ had better discriminate ability. Comparison of IRT results to the statistically significant differences found by age group in **Table 6** did not help make this decision, as both the IRT-75 and IRT- whole sample items were statistically significantly associated with age group, with high age being our proxy for frailty. What this comparison does indicate is the construct validity of both the IRT-whole sample and IRT-75+ when considering age as the construct for comparison.

After deciding to move forward with the IRT-75+ version (identified as SCREEN-IRT from here on), two additional curves were created on the 8-selected items. These curves were based on the total sample of 20,093 participants. Results from the test-information function (TIF) across the range of the nutritional risk scores confirms that the 8-item measure IRT- 75+ provides high accuracy for capturing those older adults who are at nutrition risk (**Figure 5**). The second curve within the graph depicts the standard error at different levels of risk and is an inverse reflection of the test-

information function curve. This curve was lower for those at high nutrition risk which is a good indication that the measure is doing its intended job, as the lower the score the higher the person is at nutrition risk. The predicted test score analysis results indicate that using the abbreviated measure, there is a positive relationship between the latent trait (nutrition risk) and the expected true score, meaning that this screening tool is generally effective in measuring nutrition risk across the whole sample, although it is more sensitive at the lower end of nutrition risk (participants with low nutrition risk) (**Figure 6**).

Testing the model fit of the shortened version (**Table 9**), the M2 statistic was 2247.87 ($df = 20$, $p < 0.0001$) and the M2- based root mean square error of approximation (RMSEA) was 0.075 which signifies an acceptable fit for the model (between 0.05 and 0.08). The standardized root mean square residual (SRMSR = 0.05) signifies a good fit (< 0.08) (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The Tucker-Lewis Index (TLI) at 0.868 was below and the Comparative Fit Index (CFI) at 0.905 was above the 'relaxed' good fit threshold of greater than 0.90 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006).

SCREEN-8 and SCREEN-Frail were similarly analysed in the Nutri-eSCREEN sample to assess item and test information, standard error, predicted true score and model fit. Both the test information function and the true predicted score curve was very similar across all three abbreviated versions. **Figure 7** represents the TIF curve for

SCREEN-8 while **Figure 8** represents the TIF curve for SCREEN-Frail. **Figure 9** represents the expected true score prediction curve for SCREEN-8 and **Figure 10** represents the expected true score prediction curve for SCREEN-Frail. Testing the model fit of the SCREEN-8 version (**Table 10**), the M2 statistic was 1663.26 ($df = 20$, $p < 0.0001$) and the RMSEA = 0.064, which signifies an acceptable fit for the model (between 0.05 and 0.08). The SRMSR = 0.046 satisfied the suggested cut-off value of < 0.08 for good fit (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The TLI at 0.878 was below and CFI at 0.913 was above the 'relaxed' good fit threshold of greater than 0.90 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). Testing the model fit of the SCREEN-Frail version (**Table 11**), the M2 statistic was 2720.74 ($df = 20$, $p < 0.0001$) and the M2- based RMSEA was 0.082 which signifies a mediocre fit (between 0.08 and 0.10) (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The SRMSR = 0.062 satisfied the suggested cut-off values of < 0.08 for good fit (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The TLI at 0.835 and the CFI at 0.882 did not meet at the 'relaxed' good fit threshold of greater than 0.90 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006).

Figure 5 Item Response Theory Test Information Curve depicting Test Information (precision) and Standard Error (variability in estimation) across nutrition risk levels for SCREEN-IRT

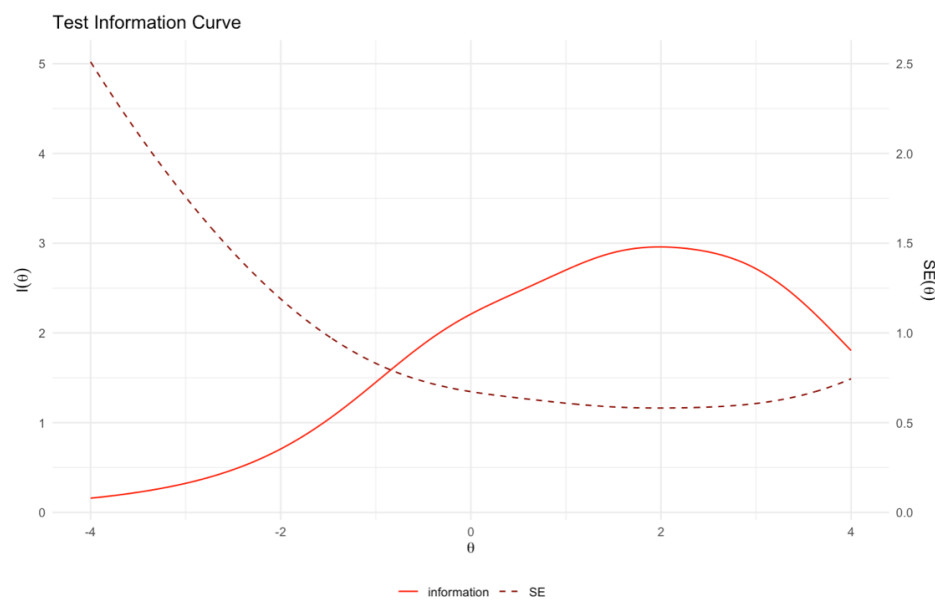


Figure 6 Expected True Score prediction curve for SCREEN-IRT using Item Response Theory, showing the tool is effective in measuring nutrition risk across the whole population

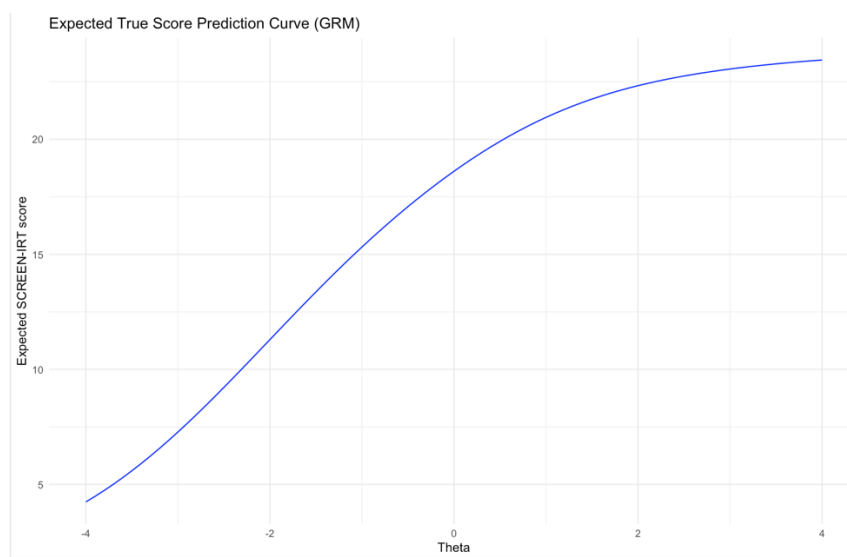


Table 9 Assessment of unidimensionality in SCREEN-IRT: model fit statistics

	M2	df	p-value	RMSEA	RMSEA_5	RMSEA_95	SRMSR	TLI	CFI
stats	2247.87	20	<0.0001	0.075	0.072	0.077	0.055	0.868	0.905

M2: Chi squared statistic

RMSEA: Root Mean Square Error of Approximation; with lower bound (5th percentile) and upper bound (95th percentile)

SRMSR: Standardized Root Mean Square Residual

TLI: Tucker-Lewis Index

CFI: Comparative Fit Index

Figure 7 Item Response Theory Test Information Curve depicting Test Information (precision) and Standard Error (variability in estimation) across nutrition risk levels for SCREEN-8

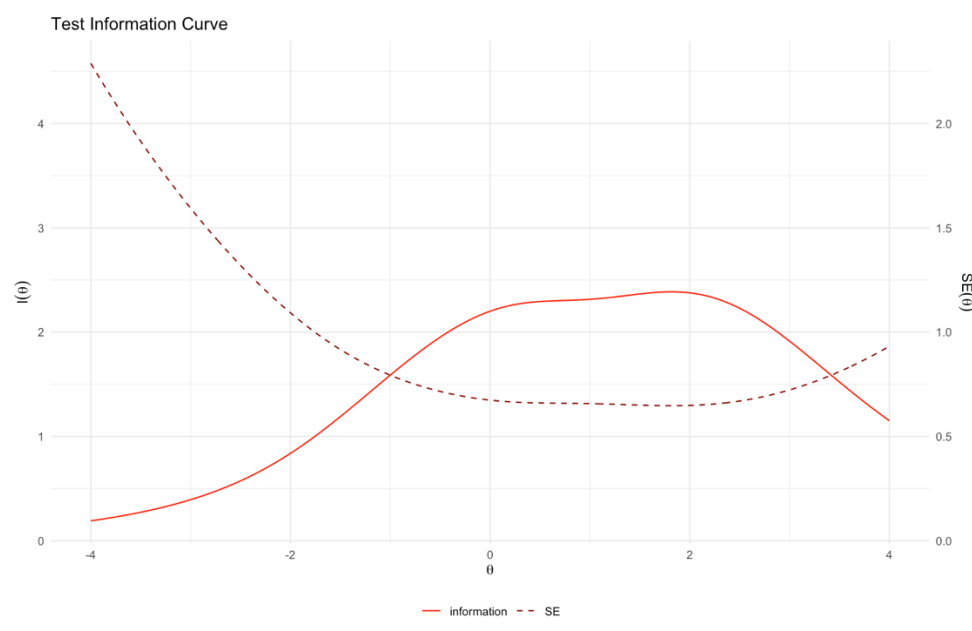


Figure 8 Expected True Score prediction curve for SCREEN-8 using Item Response Theory, showing the tool is effective in measuring nutrition risk across the whole population

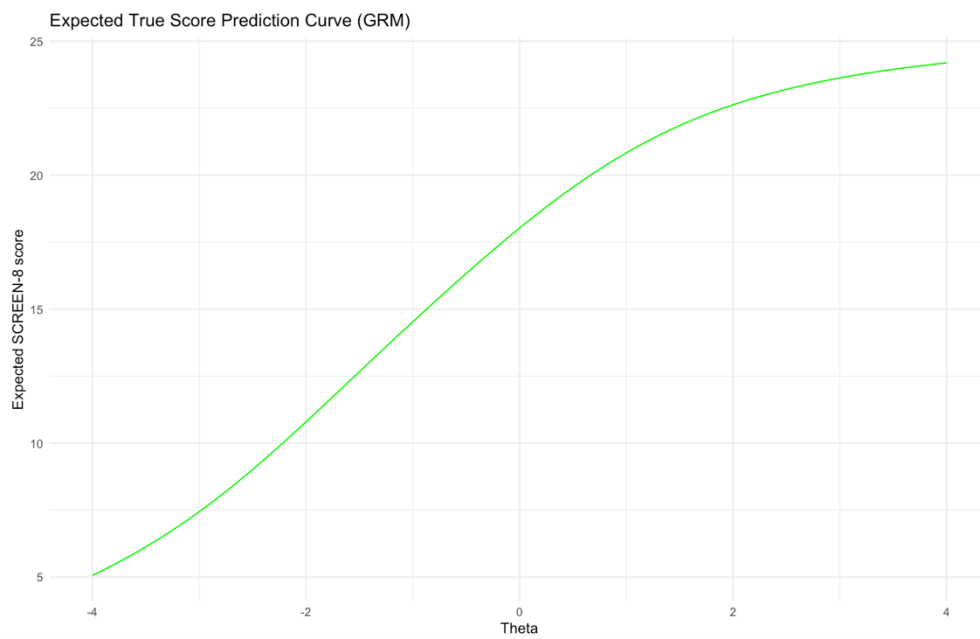


Table 10 Assessment of unidimensionality in SCREEN-8: model fit statistics

	M2	df	p-value	RMSEA	RMSEA_5	RMSEA_95	SRMSR	TLI	CFI
stats	1663.26	20	<0.0001	0.064	0.061	0.067	0.046	0.878	0.913

M2: Chi squared statistic

RMSEA: Root Mean Square Error of Approximation; with lower bound (5th percentile) and upper bound (95th percentile)

SRMSR: Standardized Root Mean Square Residual

TLI: Tucker-Lewis Index

CFI: Comparative Fit Index

Figure 9 Item Response Theory Test Information Curve depicting Test Information (precision) and Standard Error (variability in estimation) across nutrition risk levels for SCREEN-Frail

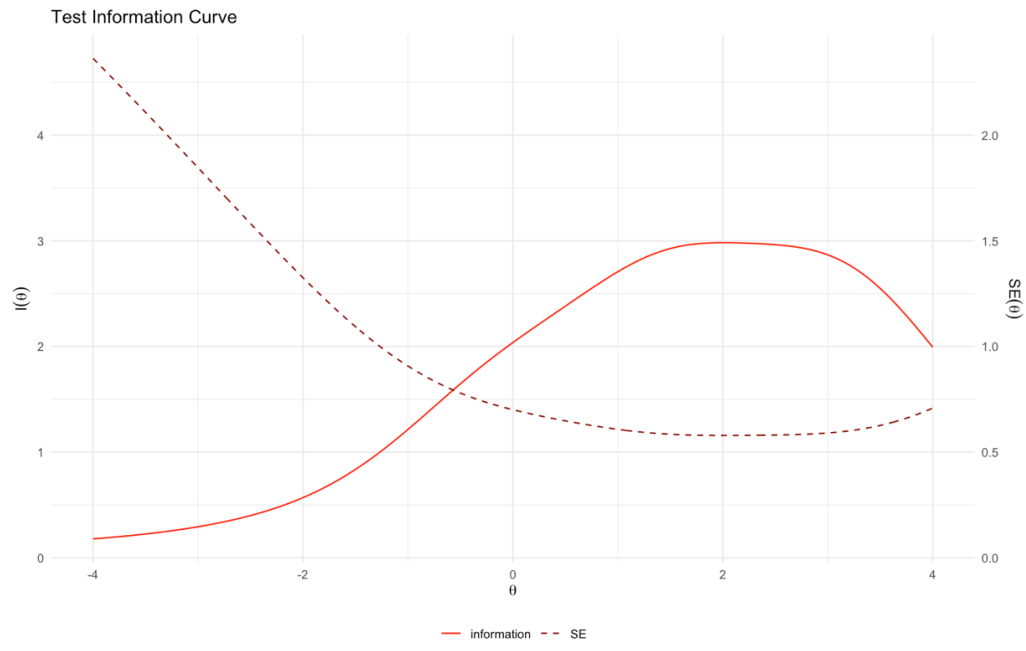


Figure 10 Expected True Score prediction curve for SCREEN-Frail using Item Response Theory, showing the tool is effective in measuring nutrition risk across the whole population

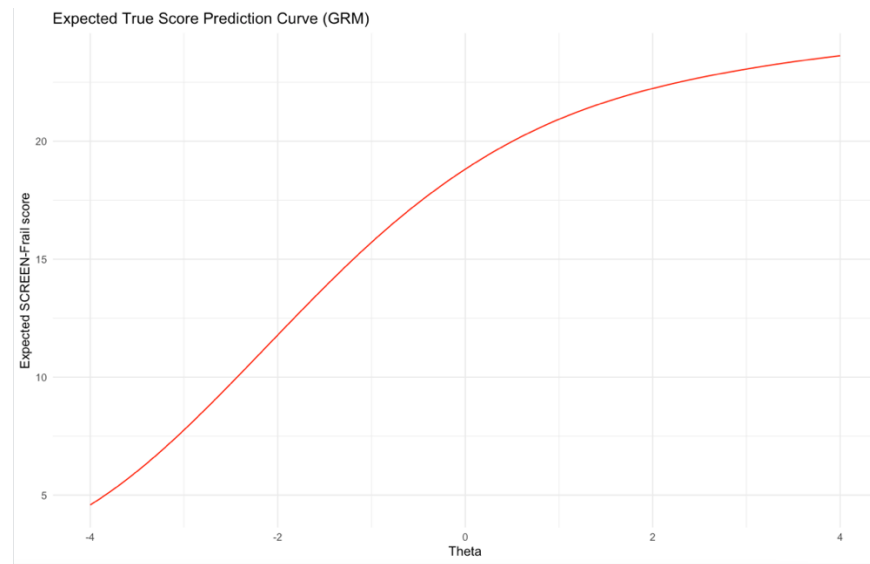


Table 11 Assessment of unidimensionality in SCREEN-Frail: model fit statistics

	M2	df	p-value	RMSEA	RMSEA_5	RMSEA_95	SRMSR	TLI	CFI
stats	2720.74	20	<0.0001	0.082	0.079	0.085	0.062	0.835	0.882

M2: Chi squared statistic

RMSEA: Root Mean Square Error of Approximation; with lower bound (5th percentile) and upper bound (95th percentile)

SRMSR: Standardized Root Mean Square Residual

TLI: Tucker-Lewis Index

CFI: Comparative Fit Index

5.5.2 Overlap of Abbreviated SCREEN Versions

To make the at risk cut-point comparable for all three versions, SCREEN-8 and SCREEN-Frail had to have all questions unweighted; an 'at risk' ≤ 22 cut point was chosen to compare prevalence and overlap among the tools. The proportion of older adults at risk using the cut-point of ≤ 22 for SCREEN-8 was 42.1%, while for SCREEN-Frail risk was 33.6% and the proportion of older adults at risk using the questions from SCREEN-IRT was 27.7%. Keeping with the same cut-point, the overlap of people 'at risk' between SCREEN-8 and SCREEN-Frail was 83.2%, while the overlap of older adults 'at risk' between SCREEN-8 and SCREEN-IRT was 90.6%. The overlap between SCREEN-Frail and SCREEN-IRT was 81.3%. Lastly, the overlap between all three versions was 77.4%. The visual representation of the overlap between the three versions is shown in **Figure 11**. Another visual to see the overlap of questions between the versions is shown in **Table 12**. Additionally, the kappa statistic was used to determine agreement on risk categorization for each version. The kappa statistic for SCREEN-8 compared to SCREEN-Frail using the weighted version for both (cut-point < 38), had a kappa of 0.88 indicating almost perfect agreement. The kappa statistic for SCREEN-8 compared to SCREEN-IRT (cut-point ≤ 22), had a kappa of 0.80 indicating substantial agreement. Lastly, the kappa statistic for SCREEN-Frail compared to SCREEN-IRT (cut-point ≤ 22), was 0.83 indicating almost perfect agreement.

Figure 11 Venn-Diagram of the overlap of the three versions of SCREEN with the cut-point of ≤ 22

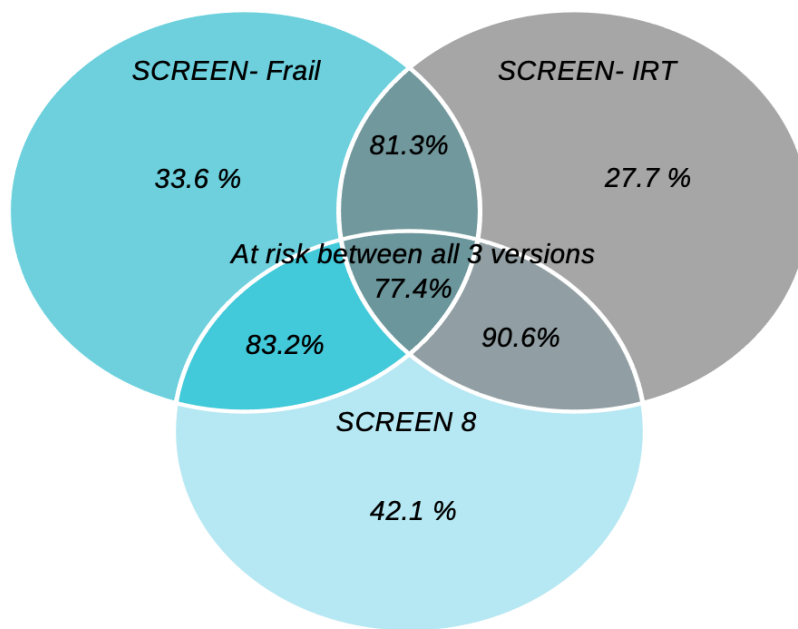


Table 12 SCREEN Questions for Each Version

SCREEN-14	SCREEN-8	SCREEN-Frail	SCREEN-IRT
1) Weight change/intention/perception	1) Weight change	1) Weight change	1) Weight change
2) Skipping meals	2) Skipping meals	2) Skipping meals	2) Weight change intention
3) Food avoidance	3) Appetite	3) Appetite	3) Skipping meals
4) Appetite	4) Difficulty swallowing	4) Difficulty swallowing	4) Appetite
5) Vegetable & fruit intake	5) Vegetable & fruit intake	5) Difficulty chewing	5) Vegetable & fruit intake
6) Meat, egg, fish, poultry, tofu, bean, lentil, & nut intake	6) Fluid intake	6) Meat, egg, fish, poultry, tofu, bean, lentil, & nut intake	6) Fluid intake
7) Dairy & soy intake	7) Eating with others	7) Dairy & soy intake	7) Difficulty chewing
8) Fluid intake	8) Meal preparation	8) Ability to grocery shop	8) Ability to grocery shop
9) Difficulty swallowing			
10) Difficulty chewing			
11) Meal replacement use			
12) Eating with others			
13) Meal preparation			
14) Ability to grocery shop			

5.6 Discussion

This study employed the Graded Response Model from the Item Response Theory to evaluate each question in SCREEN-14 from the database of the online platform Nutri-eSCREEN developed for screening for nutrition risk in community-dwelling older adults, with the intention of creating an abbreviated version of SCREEN. Through item-level estimation of discrimination (slope) and location (*b*) parameters and through discussions with the research team, an eight-item measure was produced. Through comparing the IRT version to SCREEN-8 and SCREEN-Frail, it is evident that they are all very similar, although there are some notable differences. All of the brief versions of SCREEN cover the concept of nutrition risk, including weight change, food intake and risk for food intake items. Further, there is considerable overlap in items, resulting in high kappa statistics and proportion of overlap in the Venn diagrams. Additionally, there is an overlap of five questions between SCREEN-IRT and SCREEN-Frail, resulting in a high association and almost perfect agreement between the versions indicated by the kappa statistic.

Despite this notable overlap in item content and identification of those at risk, the model fitting analysis identified important differences for determining which tool should be used going forward as an abbreviated tool. SCREEN-8 and SCREEN-IRT were both found to have good fitting models. Yet, SCREEN-8 was shown through model fitting to be a slightly better model for fitting the construct of nutrition risk in this data set.

SCREEN-8's CFI was the highest meeting the good fit threshold of greater than 0.90

(Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006) whereas the other versions were below this threshold. When determining people deemed as 'at risk' SCREEN-8 also performed better than SCREEN-Frail and SCREEN-IRT finding 42.1% of older adults in this sample to be at risk. With screening tools, if sensitivity and specificity are not both high, it is better to choose cut points that screen people in as at risk (high sensitivity) rather than screening people out (high specificity) in clinical practice (Keller et al., 2005). Misclassification is important to avoid in any screening tool, but specifically avoiding a false negative as compared to a false positive. For SCREEN, a false negative could result in an older adult continuing with their current dietary patterns and not being offered services which could lead to worsening nutritional health (Reber et al., 2019).

After completing this IRT analysis and the comparisons among the three versions, it is evident that it is appropriate to continue using SCREEN-8 in practice. The intent of this study was to see if there was a shorter or better version than SCREEN-8, and it proved that there is not. In the validity testing of SCREEN-14, SCREEN-8 was created through a mixed methods approach, where twenty-one dietitians ranked the best questions on the concept of nutritional risk and regression confirmed candidates for the inclusion of the shortened version (Keller et al., 2005). At the time of the creation of SCREEN-8, frailty was not well described in the literature. Thus, the exploration of a new version of SCREEN, with the concept of frailty in mind was undertaken. Frailty is

now of high importance and the population of older adults is rapidly increasing and frailty is becoming more prominent in the population (Canadian Frailty Network, 2019). The overlap between SCREEN-Frail and SCREEN-8 (83% of those at risk are the same and kappa= 0.78) suggests that SCREEN-8 is consistent with a version solely identified by expert opinion to be a potentially useful tool for identifying risk in older adults. Further, SCREEN-8 has documented construct, criterion and predictive validity in several studies to date (Keller & Trinca, 2023; Keller et al., 2005; Ramage-Morin et al., 2017). Despite the conclusion that SCREEN-8 is the best tool, this study provided more evidence to support the claim that SCREEN-8 is in fact the best brief model.

5.6.1 Limitations

The first limitation of this study is the sample chosen for analysis. Due to the self-report nature of the Nutri-eSCREEN platform, users may have been misclassified as being a first-time user. This would mean potential replicates of individuals in the data set that could have potentially biased some of the data (Mazor et al., 2002) and result in lack of independence of some case observations. A limitation in this study is how the best IRT model was selected. There was only a discussion between two of the researchers (MJ and HK) and experts were not contacted to give their input on the best IRT model. There is a potential that HK is biased as HK created the original SCREEN tool, and MJ is an emerging researcher. Having expert opinion would help in

determining the best model. Another potential limitation of this study is the lack of potential constructs for validation, as the survey only included age and sex (Flake et al., 2017). Another limitation is that no gender identity questions were asked to the older adults on the Nutri-eSCREEN survey prior to the SCREEN questions. In future, gender identity is more relevant to collect than sex as nutrition behaviours are gendered e.g. grocery shopping. Lastly, there is no information on diversity collected in this sample of older adults, thus not having available rich data to understand who is completing the screening tool and if there was diverse groups in the dataset based on cultural food habits.

5.6.2 Strengths

A strength to the Nutri-eSCREEN dataset was the amount of people included (n=20,093). When conducting an analysis like IRT, the model is focusing on response patterns and the more participants you have the more patterns are possible. A big strength to the analysis was the usage of the IRT to identify an abbreviated version of SCREEN. This model is a better theory than others used in the past, such as Classical Test Theory, because the same items used in different samples will keep their statistical properties such as item discrimination and difficulty, and a person's scores that represent the latent trait (nutrition risk) will not be dependent on the screening tool they use (either SCREEN-14 or other versions of SCREEN) (Zanon et al., 2016).

5.5 Conclusion

This study analyzed the seventeen items in SCREEN-14 from the Nutri-eSCREEN dataset and proposed a shortened version. A new brief version that was unique as compared to SCREEN-8 and SCREEN-Frail was identified, SCREEN-IRT. SCREEN-IRT and SCREEN-8 were similar in their model fit, although SCREEN-8 identified more participants to be at risk, while SCREEN-IRT found the smallest proportion at risk. At this point SCREEN-8 can continue to be used with confidence, recognizing that it has strong parameters with respect to model fit as compared to SCREEN-IRT and SCREEN-Frail and no shorter version was identified with IRT. Future validation testing of SCREEN-IRT and SCREEN-Frail in different populations with a criterion is warranted.

5.6 References

- Anderson, M., & Perrin, A. (2017). *Tech Adoption Climbs Among Older Adults*. Pew Research Center. <https://www.pewresearch.org/internet/2017/05/17/technology-use-among-seniors/>
- Byrne, B. M. (1994). *Structural equation modeling with EQS and EQS/Windows*. Thousand Oaks, CA: Sage Publications.
- Canadian Frailty Network. (2019). *Addressing the frailty crisis: meeting the healthcare and social services needs of older Canadians*. Canadian Frailty Network (CFN). <https://www.ourcommons.ca/Content/Committee/421/FINA/Brief/BR10596047/br-external/CanadianFrailtyNetwork-0104706-f.pdf>
- Canadian Institute for Health Information. (2017). *Infographic: Canada's seniors population outlook: Uncharted territory*. CIHI. <https://www.cihi.ca/en/infographic-canadas-seniors-population-outlook-uncharted-territory>
- Corral-Pérez, J., Ávila-Cabeza-de-Vaca, L., González-Mariscal, A., Espinar-Toledo, M., Ponce-González, J. G., Casals, C., & Vázquez-Sánchez, M. Á. (2023). Risk and protective factors for frailty in pre-frail and frail older adults. *International Journal of Environmental Research and Public Health*, 20(4), 3123. <https://doi.org/10.3390/ijerph20043123>
- Dodeen, H., & Al-Darmaki, F. (2016). The application of item response theory in developing and validating a shortened version of the Emirate Marital Satisfaction Scale. *Psychological Assessment*, 28(12), 1625–1633. <https://doi.org/10.1037/pas0000296>
- Donnelly, R., Devlin, K., & Keller, H. (2022). Dietitian perspectives: Are we ready for nutrition risk screening in community and primary care? *The Journal of Nutrition, Health and Aging*, 26(2), 211–212. <https://doi.org/10.1007/s12603-022-1735-6>
- Edelen, M. O., & Reeve, B. B. (2007). Applying item response theory (IRT) modeling to questionnaire development, evaluation, and refinement. *Quality of life research*, 16, 5-18.
- Flake, J. K., Pek, J., & Hehman, E. (2017). Construct validation in social and Personality Research. *Social Psychological and Personality Science*, 8(4), 370–378. <https://doi.org/10.1177/1948550617693063>

- Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., & McBurnie, M. A. (2001). Frailty in older adults: Evidence for a phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(3). <https://doi.org/10.1093/gerona/56.3.m146>
- Government of Canada, Statistics Canada. (2022). Projected population, by projection scenario, age and sex, as of July 1. <https://doi.org/10.25318/1710005701-eng>
- Hays, R. D., Morales, L. S., & Reise, S. P. (2000). Item response theory and health outcomes measurement in the 21st Century. *Medical Care*, 38. <https://doi.org/10.1097/00005650-200009002-00007>
- Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct. Equ. Modeling* 6, 1–55.
- Jiang, S., Wang, C., & Weiss, D. J. (2016). Sample Size Requirements for estimation of item parameters in the multidimensional graded response model. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.00109>
- Keller, Heather H. (2016). Nutri-eSCREEN®: Descriptive Analysis of a self-management site for older adults (50+ years). *BMC Nutrition*, 2(1). <https://doi.org/10.1186/s40795-015-0041-7>
- Keller, H. H., Hedley, M. R., & Wong Brownlee, S. (2000). The Development of Seniors in the Community: Risk Evaluation for Eating and Nutrition (SCREEN). *Canadian journal of dietetic practice and research : a publication of Dietitians of Canada = Revue canadienne de la pratique et de la recherche en dietetique : une publication des Dietetistes du Canada*, 61(2), 67–72.
- Keller, H H, Goy, R., & Kane, S.-L. (2005). Validity and reliability of screen II (seniors in the community: Risk evaluation for eating and nutrition, version II). *European Journal of Clinical Nutrition*, 59(10), 1149–1157. <https://doi.org/10.1038/sj.ejcn.1602225>
- Keller, H. H., & Trinca, V. (2023). Determinants of a decline in a nutrition risk measure differ by Baseline High Nutrition Risk Status: Targeting nutrition risk screening for frailty prevention in the Canadian Longitudinal Study on Aging (CLSA). *Canadian Journal of Public Health*, 114(4), 593–612. <https://doi.org/10.17269/s41997-023-00745-w>

- Kost, R. G., & Correa da Rosa, J. (2018). Impact of survey length and compensation on validity, reliability, and sample characteristics for ultrashort-, short-, and long-research participant perception surveys. *Journal of Clinical and Translational Science*, 2(1), 31–37. <https://doi.org/10.1017/cts.2018.18>
- Lorenzo-López, L., Maseda, A., de Labra, C., Regueiro-Folgueira, L., Rodríguez-Villamil, J. L., & Millán-Calenti, J. C. (2017). Nutritional determinants of frailty in older adults: A systematic review. *BMC Geriatrics*, 17(1). <https://doi.org/10.1186/s12877-017-0496-2>
- Lubbe, D., & Schuster, C. (2018). A graded response model framework for questionnaires with uniform response formats. *Applied Psychological Measurement*, 43(4), 290–302. <https://doi.org/10.1177/0146621618789394>
- Mazor, K. M., Clauser, B. E., Field, T., Yood, R. A., & Gurwitz, J. H. (2002). A demonstration of the impact of response bias on the results of patient satisfaction surveys. *Health Services Research*, 37(5), 1403–1417. <https://doi.org/10.1111/1475-6773.11194>
- McHugh, M. L. (2012). Interrater Reliability: The kappa statistic. *Biochemia Medica*, 276–282. <https://doi.org/10.11613/bm.2012.031>
- Microsoft Corporation. (2021). Microsoft Excel [Software]. Available from <https://www.microsoft.com>
- Nguyen, T. H., Han, H.-R., Kim, M. T., & Chan, K. S. (2014). An introduction to item response theory for patient-reported outcome measurement. *The Patient - Patient-Centered Outcomes Research*, 7(1), 23–35. <https://doi.org/10.1007/s40271-013-0041-0>
- Ostini, R., & Nering, M. (2006). Polytomous Item response theory models. *Sage Research Methods*. <https://doi.org/10.4135/9781412985413>
- Raykov, T., Dimitrov, D. M., Marcoulides, G. A., & Harrison, M. (2019). On true score evaluation using item response theory modeling. *Educational and Psychological Measurement*, 79(4), 796–807. <https://doi.org/10.1177/0013164417741711>
- Reise, S. P., Widaman, K. F., & Pugh, R. H. (1993). Confirmatory factor analysis and item response theory: Two approaches for exploring measurement invariance. *Psychological Bulletin*, 114(3), 552–566. <https://doi.org/10.1037/0033-2909.114.3.552>

- RStudio Team. (2024). RStudio: Integrated Development Environment for R [Software]. RStudio,PBC. Available at <https://www.rstudio.com/>
- Sethar, W. A., Pitafi, A., Bhutto, A., Nassani, A. A., Haffar, M., & Kamran, S. M. (2022). Application of item response theory (irt)-graded response model (GRM) to Entrepreneurial Ecosystem Scale. *Sustainability*, 14(9), 5532. <https://doi.org/10.3390/su14095532>
- Stenbeck, M., Hambleton, R. K., Swaminathan, H., & Rogers, H. J. (1992). Fundamentals of item response theory. *Contemporary Sociology*, 21(2), 289. <https://doi.org/10.2307/2075521>
- Volkert, D., Kiesswetter, E., Cederholm, T., Donini, L. M., Eglseer, D., Norman, K., Schneider, S. M., Ströbele-Benschop, N., Torbahn, G., Wirth, R., & Visser, M. (2019). Development of a model on determinants of malnutrition in aged persons: A Manuel Project. *Gerontology and Geriatric Medicine*, 5, 2333721419858438. <https://doi.org/10.1177/2333721419858438>
- Walston, J., Buta, B., & Xue, Q.-L. (2018). Frailty screening and interventions. *Clinics in Geriatric Medicine*, 34(1), 25–38. <https://doi.org/10.1016/j.cger.2017.09.004>
- Wang, X., Hu, J., & Wu, D. (2022). Risk factors for frailty in older adults. *Medicine*, 101(34). <https://doi.org/10.1097/md.00000000000030169>
- Weston, R., and Gore, P. A. Jr. (2006). A brief guide to structural equation modeling. *Couns. Psychol.* 34, 719–751.
- Xia, Y., & Yang, Y. (2018). RMSEA, CFI, and TLI in structural equation modeling with ordered categorical data: The story they tell depends on the estimation methods. *Behavior Research Methods*, 51(1), 409–428. <https://doi.org/10.3758/s13428-018-1055-2>
- Xie, Y. (2017). *Bookdown: Authoring books and technical documents with R Markdown*. Boca Raton, FL: CRC Press
- Zanon, C., Hutz, C. S., Yoo, H., & Hambleton, R. K. (2016). An application of item response theory to psychological test development. *Psicologia: Reflexão e Crítica*, 29(1). <https://doi.org/10.1186/s41155-016-0040-x>

CHAPTER 6: DISCUSSION

6.1 Overview

In the past twenty years or so, there has been an increase in nutrition risk screening tools created in a variety of settings such as hospitals, community, rehabilitation, and long-term care (Power et al., 2018). It is widely acknowledged the importance of good nutritional status in the aging population to encourage the maintenance of health and delay the progression of disease (Russell et al., 2012). It is also becoming widely recognized that screening for nutrition risk is an important first step to identifying those who are at risk and so that the right nutritional care can be provided to improve outcomes such as frailty (Laur & Keller, 2017). Of the current screening tools in use that have undergone validation testing, none have evidence that they have been specifically validated in a frail population. One of the current screening tools, SCREEN-14 had the most evidence for validity for the community setting (Power et al., 2018). With this in mind, SCREEN was used in this research to further the application of this tool through validation for the community population of potentially frail older adults. The studies in this thesis were designed to evaluate content validity through expert opinion and construct validity to analyze item level characteristics of SCREEN-14, as well as selecting questions for inclusion in a brief version of SCREEN for a frail population.

6.2 Summary of Key Findings

Chapter 4 presents a Delphi study (n=18) to confirm and expand SCREEN for a frail population. This was completed through two-rounds of the Delphi, in which experts identified eight existing questions from SCREEN-14 as a potential subset to identify nutrition risk in frail older adults. Of the eighteen participants, twelve participants completed round one (27.9% response rate), and fifteen completed round two (34.9% response rate); nine out of the fifteen were consistent across rounds (60% of participants). The eight questions that were identified as ‘most important’ to include in the final set are: weight change, skipping meals, appetite, difficulty swallowing, difficulty chewing, protein intake, dairy and soy intake, and ability to grocery shop. As content validity has only been determined for SCREEN-Frail, further construct and criterion validation are necessary before this brief tool is used in practice.

Chapter 5 examines the item-level properties of SCREEN-14 from the Nutri-eSCREEN dataset using IRT, specifically the GRM, with the aim of identifying items suitable for inclusion in a shortened version. The IRT version contained eight questions. Two versions of the IRT were derived from the dataset. The ages 75+ IRT was selected as the ‘better’ version because it provided better coverage of the core components of risk: weight change, reduced food intake and risk factors for poor food intake, and better IRCC plots and statistics. The age 74-84 and 85+ groups had the highest proportions in the responses that correlate with nutrition risk for all SCREEN-14 items. Meaningful

differences in total mean scores across age groups was also observed ($p < 0.0001$).

Differences in scores between sex were also observed in individual SCREEN items.

The two new versions of SCREEN (SCREEN-Frail and SCREEN-IRT) were compared to SCREEN-8 to identify who is at risk among these three versions. In SCREEN-8 (unweighted) 42.1% were deemed as at risk with the cut-point of ≤ 22 . With SCREEN-Frail (created from **Chapter 4**), 33.6% were at risk and 27.7% with SCREEN-IRT using the same cut-point of ≤ 22 . The overlap in identification of those at risk in all three versions using the same cut-point of ≤ 22 was 77.4%. Additionally, the proportion of overlap for people at risk between SCREEN-8 and SCREEN-Frail was 83.2%, between SCREEN-8 and SCREEN-IRT was 90.6%, and between SCREEN-Frail and SCREEN-IRT was 81.3%. Items in the SCREEN-IRT demonstrate high item information at the lower end of nutrition risk, a high standard error at the higher end of nutrition risk. The model fit statistics for SCREEN-IRT had a RMSEA of 0.075 which signifies an acceptable fit for the model (between 0.05 and 0.08). The SRMSR = 0.05 signifies a good fit (< 0.08) (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The TLI at 0.868 was below and the CFI at 0.905 was above the 'relaxed' good fit threshold of greater than 0.90 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). Thus, demonstrating good model fit. Due to the results from the overlap of risk, it was decided to conduct the analysis of unidimensionality on the questions in SCREEN-8 and SCREEN-Frail. SCREEN-8 had a RMSEA = 0.064, which signifies an acceptable fit for

the model (between 0.05 and 0.08). The SRMSR = 0.046 satisfied the suggested cut-off value of <0.08 for good fit (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). The TLI at 0.878 was below and CFI at 0.913 was above the 'relaxed' good fit threshold of greater than 0.90 (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). Indicating a good model of fit. Lastly, SCREEN-Frail had a RMSEA of 0.082 which signifies a mediocre fit (between 0.08 and 0.10). The SRMSR = 0.062 satisfied the suggested cut-off values of <0.08 for good fit (Hu & Bentler, 1999; Sethar et al., 2022; Weston & Gore, 2006). TLI at 0.835 and CFI at 0.882 did not meet at the 'relaxed' good fit threshold of greater than 0.90, demonstrating a mediocre model of fit. Further validation of SCREEN-IRT should be undertaken before it is considered for clinical or research purposes.

6.3 Contribution to Current Knowledge

This research highlights the importance of having valid and reliable screening tools for nutrition risk in the frail older adult population. It is important to have valid tools to ensure accurate identification of those at risk (Power et al., 2018). The importance of continuing to test and adjust nutrition risk screening tools is to determine if they are applicable in diverse populations and contexts. A tool can never be fully valid in every population, but it is important to test the screening tool in a wide variety of populations but in particular those most at risk. The population that is 'most at risk' is the frail older

population. In current literature, there are no valid tools to use specifically in the frail community population. These studies largely contribute to considering if adjustments should be made to the SCREEN tool to focus on the frail population and those who are in the older range of older adults (75+). The versions of SCREEN (SCREEN-Frail and SCREEN-IRT) are brief versions of the full SCREEN-14, aligning with the principles of good screening practices as it is a quick and simple procedure (Public Health England, 2022) that can be done at home or over the phone. However, both versions have differences in item content, demonstrating how different development and testing methods can result in different questionnaires (see **Table 12**). When directed to consider frailty and identifying risk in those who are frail, experts highlighted food components of SCREEN that assessed protein and calcium intake. Further, they also chose four items that had previously been identified in SCREEN development to be essential for the determination of risk: weight change, skipping meals, poor appetite, and difficulty swallowing. In SCREEN-8 and now SCREEN-Frail, these items are double-weighted to give greater value to their determination of risk. Notably, the statistical process for creating SCREEN-IRT only identified three of these essential items and added in intentionality of weight change as a key item. Similar to SCREEN-8, the only consumption items on SCREEN-IRT are fruit and vegetable and fluid intake, but risk factors are not consistent with SCREEN-8. SCREEN-IRT and SCREEN-Frail overlap on these risk factors that can impair food intake: chewing difficulty and grocery

shopping difficulty. These studies contribute to the growing evidence of nutrition risk screening tools in the community and demonstrate that the briefest a SCREEN questionnaire can be is eight items.

6.4 Overall Strengths and Limitations

The studies in this thesis should be viewed with the understanding that every study has its flaws, but it is also having strengths that can outweigh the limitations.

Chapter 4 and **Chapter 5**, focused on evaluating questions in the full version of SCREEN. In **Chapter 4**, the Delphi study aimed at gathering expert opinion used as a content validation method to confirm questions to use in a group of frail older adults (Fink-Hafner et al., 2019). The greatest strength of this study was the opinion of experts on SCREEN for selection of the eight questions used to create SCREEN-Frail. The questions agreed upon had similarities as a previous validated version of SCREEN known as SCREEN-8 (Keller et al., 2005). In **Chapter 5**, the research used a more advanced modeling technique known as the IRT. The IRT has the strength to select questions on an item level rather than the tool as a whole. This allows for accurate interpretation to including the ‘best’ statistically sound questions in a refined and brief screening tool. The large sample size (n=20,093 and aged 75+ n=2,749) is an added benefit to this IRT because the larger the sample size (>500) the more accurate the parameter estimates are (Jiang et al., 2016).

The focus of **Chapter 4** was gathering consensus thorough a Delphi method. One of the fundamental limitations of the Delphi is the results are based on the opinion of experts in the older adult nutrition community and not on primary data (Fink-Hafner et al., 2019; Hus & Sandford 2019). An additional limitation of this study is the lack of a diverse population of experts. The majority of the experts identified as white, women from either North America or Europe. In future, it would have added benefits to get a diverse population, although identifying these experts is the challenge. In **Chapter 5**, there was no information collected on the diversity of the population. Thus, we are unaware of details on the population completing the survey, and thus have limited information and no knowledge of potential cultural habits and other factors that could influence nutrition risk.

6.5 Implications of Findings

SCREEN was originally created over twenty years ago for research purposes (Keller et al., 2000). Since then, SCREEN is used in clinical practice and has been validated in a few settings, with the greatest evidence in community-dwelling older adults (Keller et al., 2005). SCREEN-8, due to its brevity and SCREEN-3 extended are preferred in clinical practice, while SCREEN-8 is used in epidemiological surveys like the Canadian Longitudinal Study on Aging. These two studies continued to improve the knowledge of SCREEN with the addition of two new versions. Beginning from **Chapter**

4, the results of the Delphi, showed that no major changes needed to be done on SCREEN-14, only certain questions could be excluded for the frail population. Despite asking experts about the addition of supplementation questions around Vitamin D and calcium, consensus was not achieved on these additions to the current tool. Additionally, four of the eight questions from SCREEN-Frail (Delphi version), are the same four questions that are double weighted from SCREEN-8, confirming the importance of these items for determining nutrition risk. Moving to **Chapter 5**, the ‘best’ version of the IRT also had a total of eight questions. With all three versions having eight questions the goal of attaining a briefer tool than SCREEN-8 in these studies was not achieved. Considering the importance of ‘screening in’ in community-settings, SCREEN-8 was the best version among the three as the most participants were identified to be ‘at risk’ (42.1%) with this version. SCREEN-IRT was better at screening out participants with a prevalence of risk at 27.7%. Clinical sites would likely prefer to use SCREEN-IRT, as there are concerns about over identifying risk, resulting in overuse of scarce dietitian resources (Keller et al. 2005). Both the SCREEN-IRT and SCREEN-8 resulted in good fitting models, when considering model fitting statistics (RMSEA, SRMSR, TLI and CFI), but the SCREEN-Frail had a mediocre fit. Further criterion validation, specifically of SCREEN-IRT, is warranted based on these results to determine if it is a better brief version than the currently available SCREEN-8.

6.6 Conclusion

The two studies in this thesis emphasize the importance of having valid and reliable tools to use in screening for nutrition risk in a community-dwelling frail older adult population. As the population is rapidly aging, easy to use and brief tools that target nutrition risk identification to those most in need of further evaluation are required. These studies helped to identify two separate potential versions of SCREEN through different methods. The different versions both contained eight questions as does SCREEN-8. Prevalence of risk varied with these tools, suggesting differences that need to be further explored. Both SCREEN-8 and SCREEN-IRT had good/adequate fitting models, suggesting minimal differences at this stage. Further validation of SCREEN-IRT is required before considering it for use in clinical and research settings. As no shorter tool was identified and SCREEN-8 held up in model fitting, it can be concluded that SCREEN-8 is sufficient for screening community-dwelling older adults. It cannot be concluded that SCREEN-8 is sufficient for frail older adults because no measure of frailty was in Nutri-eSCREEN or in the creation of SCREEN-8. Although, due to the effort of implementing SCREEN-8 in practice and the extensive validation and reliability testing of this version, significant justification (e.g. lower prevalence and better validity in different populations) beyond these two studies would need to be shown to propose SCREEN-IRT as an improvement on SCREEN-8.

CHAPTER 7: REFERENCES

- Abbasi, M., Rolfson, D., Khera, A. S., Dabravolskaj, J., Dent, E., & Xia, L. (2018). Identification and management of frailty in the primary care setting. *Canadian Medical Association Journal*, 190(38). <https://doi.org/10.1503/cmaj.171509>
- Akhtar, U., Keller, H. H., Tate, R. B., & Lengyel, C. O. (2015). Construct validation of three nutrition questions using health and diet ratings in older Canadian males living in the community. *Canadian Journal of Dietetic Practice and Research*, 76(4), 194–199. <https://doi.org/10.3148/cjdpr-2015-025>
- AlMohaisen, N., Gittins, M., Todd, C., & Burden, S. (2022). What is the overlap between malnutrition, frailty and sarcopenia in the older population? study protocol for cross-sectional study using UK Biobank. *PLOS ONE*, 17(12). <https://doi.org/10.1371/journal.pone.0278371>
- Bardon, L. A., Corish, C. A., Lane, M., Bizzaro, M. G., Loayza Villarroel, K., Clarke, M., Power, L. C., Gibney, E. R., & Dominguez Castro, P. (2021). Ageing rate of older adults affects the factors associated with, and the determinants of malnutrition in the community: A systematic review and narrative synthesis. *BMC Geriatrics*, 21(1). <https://doi.org/10.1186/s12877-021-02583-2>
- Berrazaga, I., Micard, V., Gueugneau, M., & Walrand, S. (2019). The role of the anabolic properties of plant- versus animal-based protein sources in supporting Muscle Mass Maintenance: A critical review. *Nutrients*, 11(8), 1825. <https://doi.org/10.3390/nu11081825>
- Berrut, G., Andrieu, S., Araujo De Carvalho, I., Baeyens, J. P., Bergman, H., Cassim, B., Cerreta, F., Cesari, M., Cha, H. B., Chen, L. K., Cherubini, A., Chou, M. Y., Cruz-Jentoft, A. J., De Decker, L., Du, P., Forette, B., Forette, F., Franco, A., Guimaraes, R., ... Benetos, A. (2013). Promoting access to innovation for Frail Old Persons. *The Journal of Nutrition, Health & Aging*, 17(8), 688–693. <https://doi.org/10.1007/s12603-013-0039-2>
- Bloom, I., Zhang, J., Parsons, C., Bevilacqua, G., Dennison, E. M., Cooper, C., & Ward, K. A. (2022). Nutritional risk and its relationship with physical function in community-dwelling older adults. *Aging Clinical and Experimental Research*, 34(9), 2031–2039. <https://doi.org/10.1007/s40520-022-02171-3>
- Borkent, J. W., Schuurman, L. T., Beelen, J., Linschooten, J. O., Keller, H. H., Roodenburg, A. J. C., & De van der Schueren, M. A. E. (2020). What do screening tools measure? lessons learned from

screen II and snaq65+. *Clinical Nutrition ESPEN*, 38, 172–177.
<https://doi.org/10.1016/j.clnesp.2020.05.008>

Borkent, J., Naumann, E., Vasse, E., van der Heijden, E., & De van der Schueren, M. (2019). Sun-PO238: Prevalence and determinants of undernutrition in a sample of Dutch community-dwelling older adults: Results from two online screening tools. *Clinical Nutrition*, 38.
[https://doi.org/10.1016/s0261-5614\(19\)32870-5](https://doi.org/10.1016/s0261-5614(19)32870-5)

Buchebner, D., Bartosch, P., Malmgren, L., McGuigan, F. E., Gerdhem, P., & Akesson, K. E. (2019). Association Between Vitamin D, Frailty, and Progression of Frailty in Community-Dwelling Older Women. *The Journal of Clinical Endocrinology & Metabolism*, 104(12), 6139–6147.
<https://doi.org/10.1210/jc.2019-00573>

Buhl, S. F., Beck, A. M., Olsen, P. Ø., Kock, G., Christensen, B., Wegner, M., Vaarst, J., & Caserotti, P. (2022). Relationship between physical frailty, nutritional risk factors and protein intake in community-dwelling older adults. *Clinical Nutrition ESPEN*, 49, 449458.
<https://doi.org/10.1016/j.clnesp.2022.03.004>

Cai, Y., Wanigatunga, A. A., Mitchell, C. M., Urbanek, J. K., Miller, E. R., Juraschek, S. P., Michos, E. D., Kalyani, R. R., Roth, D. L., Appel, L. J., & Schrack, J. A. (2022). The effects of vitamin D supplementation on frailty in older adults at risk for falls. *BMC Geriatrics*, 22(1).
<https://doi.org/10.1186/s12877-022-02888-w>

Canadian Frailty Network. (2019). *Addressing the frailty crisis: meeting the healthcare and social services needs of older Canadians*. Canadian Frailty Network (CFN).
<https://www.ourcommons.ca/Content/Committee/421/FINA/Brief/BR10596047/br-external/CanadianFrailtyNetwork-0104706-f.pdf>

Cederholm, T., Barazzoni, R., Austin, P., Ballmer, P., Biolo, G., Bischoff, S. C., Compher, C., Correia, I., Higashiguchi, T., Holst, M., Jensen, G. L., Malone, A., Muscaritoli, M., Nyulasi, I., Pirlich, M., Rothenberg, E., Schindler, K., Schneider, S. M., de van der Schueren, M. A. E., ... Singer, P. (2016). Espen guidelines on definitions and terminology of Clinical Nutrition. *Clinical Nutrition*, 36(1), 49–64. <https://doi.org/10.1016/j.clnu.2016.09.004>

Cederholm, T., Jensen, G. L., Correia, M. I. T. D., Gonzalez, M. C., Fukushima, R., Higashiguchi, T., Baptista, G., Barazzoni, R., Blaauw, R., Coats, A. J. S., Crivelli, A. N., Evans, D. C., Gramlich, L., Fuchs-Tarlovsky, V., Keller, H., Llido, L., Malone, A., Mogensen, K. M., Morley, J. E., ... Compher, C. (2019). Glim criteria for the diagnosis of malnutrition – a consensus report from the

Global Clinical Nutrition Community. *Journal of Cachexia, Sarcopenia and Muscle*, 10(1), 207–217. <https://doi.org/10.1002/jcsm.12383>

Cederholm, T., Jensen, G. L., Correia, M. I. T. D., Gonzalez, M. C., Fukushima, R., Higashiguchi, T., Baptista, G., Barazzoni, R., Blaauw, R., Coats, A. J. S., Crivelli, A. N., Evans, D. C., Gramlich, L., Fuchs-Tarlovsky, V., Keller, H., Llado, L., Malone, A., Mogensen, K. M., Morley, J. E., ... Compher, C. (2019). Glim criteria for the diagnosis of malnutrition – a consensus report from the Global Clinical Nutrition Community. *Journal of Cachexia, Sarcopenia and Muscle*, 10(1), 207–217. <https://doi.org/10.1002/jcsm.12383>

Coelho-Junior, Hélio J., Marzetti, E., Picca, A., Cesari, M., Uchida, M. C., & Calvani, R. (2020). Protein intake and frailty: A matter of quantity, quality, and timing. *Nutrients*, 12(10), 2915. <https://doi.org/10.3390/nu12102915>

Coelho-Junior, Hélio José, Calvani, R., Picca, A., Tosato, M., Landi, F., & Marzetti, E. (2022). Protein intake and frailty in older adults: A systematic review and meta-analysis of observational studies. *Nutrients*, 14(13), 2767. <https://doi.org/10.3390/nu14132767>

Dent, E., Martin, F. C., Bergman, H., Woo, J., Romero-Ortuno, R., & Walston, J. D. (2019). Management of frailty: Opportunities, challenges, and future directions. *The Lancet*, 394(10206), 1376–1386. [https://doi.org/10.1016/s0140-6736\(19\)31785-4](https://doi.org/10.1016/s0140-6736(19)31785-4)

Dent, E., Visvanathan, R., Piantadosi, C., & Chapman, I. (2012). Use of the Mini Nutritional Assessment to detect frailty in hospitalised older people. *The Journal of Nutrition, Health & Aging*, 16(9), 764–767. <https://doi.org/10.1007/s12603-012-0405-5>

Dent, E., Wright, O. R., Woo, J., & Hoogendijk, E. O. (2023). Malnutrition in older adults. *The Lancet*, 401(10380), 951–966. [https://doi.org/10.1016/s0140-6736\(22\)026125](https://doi.org/10.1016/s0140-6736(22)026125)

Deutz, N. E. P., Bauer, J. M., Barazzoni, R., Biolo, G., Boirie, Y., Bosy-Westphal, A., Cederholm, T., Cruz-Jentoft, A., Krznarić, Z., Nair, K. S., Singer, P., Teta, D., Tipton, K., & Calder, P. C. (2014). Protein intake and exercise for optimal muscle function with aging: Recommendations from the Espen Expert Group. *Clinical Nutrition*, 33(6), 929–936. <https://doi.org/10.1016/j.clnu.2014.04.007>

Dodd, K. (2019). *Nutritional needs for older adults: Vitamin D*. National Resource Center on Nutrition & Aging. https://acl.gov/sites/default/files/nutrition/Nutrition-Needs_Vitamin-D_FINAL_508.pdf

- Donnelly, R., & Keller, H. (2021). Challenges providing nutrition care during the COVID-19 pandemic: Canadian dietitian perspectives. *The Journal of Nutrition, Health & Aging*, 25(5), 710–711. <https://doi.org/10.1007/s12603-020-1585-z>
- Fávaro-Moreira, N. C., Krausch-Hofmann, S., Matthys, C., Vereecken, C., Vanhauwaert, E., Declercq, A., Bekkering, G. E., & Duyck, J. (2016a). Risk factors for malnutrition in older adults: A systematic review of the literature based on Longitudinal Data. *Advances in Nutrition*, 7(3), 507–522. <https://doi.org/10.3945/an.115.011254>
- Fekete, M., Szarvas, Z., Fazekas-Pongor, V., Feher, A., Csipo, T., Forrai, J., Dosa, N., Peterfi, A., Lehoczki, A., Tarantini, S., & Varga, J. T. (2022). Nutrition strategies promoting healthy aging: From improvement of cardiovascular and Brain Health to prevention of age-associated diseases. *Nutrients*, 15(1), 47. <https://doi.org/10.3390/nu15010047>
- Fried, L. P., Cohen, A. A., Xue, Q.-L., Walston, J., Bandeen-Roche, K., & Varadhan, R. (2021). The physical frailty syndrome as a transition from homeostatic symphony to Cacophony. *Nature Aging*, 1(1), 36–46. <https://doi.org/10.1038/s43587-020-00017-z>
- Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., & McBurnie, M. A. (2001). Frailty in older adults: Evidence for a phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(3). <https://doi.org/10.1093/gerona/56.3.m146>
- Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., & McBurnie, M. A. (2001). Frailty in older adults: Evidence for a phenotype. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(3). <https://doi.org/10.1093/gerona/56.3.m146>
- Gingrich, A., Volkert, D., Kiesswetter, E., Thomanek, M., Bach, S., Sieber, C. C., & Zopf, Y. (2019). Prevalence and overlap of sarcopenia, Frailty, cachexia and malnutrition in older medical inpatients. *BMC Geriatrics*, 19(1). <https://doi.org/10.1186/s12877-019-1115-1>
- Guigoz, Y., & Vellas, B. (2021). Nutritional assessment in older adults: MNA® 25 years of a Screening Tool & A Reference Standard for care and research; what next? *The Journal of Nutrition, Health & Aging*, 25(4), 528–583. <https://doi.org/10.1007/s12603-021-1601-y>

- Haakma, T. A., & Wham, C. A. (2015). High prevalence of nutrition risk among community living older people in Woerden, the Netherlands. *Journal of Aging Research and Lifestyle*, 1–5. <https://doi.org/10.14283/jarcp.2015.77>
- Health Canada. (2021). *Vitamin D*. Canada.ca. <https://www.canada.ca/en/health-canada/services/drugs-health-products/drug-products/prescription-drug-list/notices-changes/notice-amendment-vitamin-d.html>
- Health Canada. (2022). *Vitamin D*. Canada.ca. <https://www.canada.ca/en/health-canada/services/nutrients/vitamin-d.html>
- Health Canada. (2024). *Fortified foods: Canada's approach to fortification*. Canada.ca. <https://www.canada.ca/en/health-canada/services/fortified-food/canadas-approach.html>
- Hernández Morante, J. J., Gómez Martínez, C., & Morillas-Ruiz, J. M. (2019). Dietary factors associated with frailty in old adults: A review of nutritional interventions to prevent frailty development. *Nutrients*, 11(1), 102. <https://doi.org/10.3390/nu11010102>
- Hoogendijk, E. O., Afilalo, J., Ensrud, K. E., Kowal, P., Onder, G., & Fried, L. P. (2019). Frailty: Implications for clinical practice and Public Health. *The Lancet*, 394(10206), 1365–1375. [https://doi.org/10.1016/s0140-6736\(19\)31786-6](https://doi.org/10.1016/s0140-6736(19)31786-6)
- Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct. Equ. Modeling* 6, 1–55.
- Institute of Medicine. (2011). Dietary reference intakes for calcium and vitamin D. (A. C. Ross, C. L. Taylor, A. L. Yaktine, & H. B. Del Valle, Eds.). *National Academies Press*. <https://doi.org/10.17226/13050>
- Jeejeebhoy, K. N. (2012). Malnutrition, fatigue, frailty, vulnerability, sarcopenia and Cachexia. *Current Opinion in Clinical Nutrition and Metabolic Care*, 15(3), 213–219. <https://doi.org/10.1097/mco.0b013e328352694f>
- Jiang, S., Wang, C., & Weiss, D. J. (2016). Sample Size Requirements for estimation of item parameters in the multidimensional graded response model. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.00109>

- Keller, H H, Goy, R., & Kane, S.-L. (2005). Validity and reliability of screen II (seniors in the community: Risk evaluation for eating and nutrition, version II). *European Journal of Clinical Nutrition*, 59(10), 1149–1157. <https://doi.org/10.1038/sj.ejcn.1602225>
- Keller, H H, Goy, R., & Kane, S.-L. (2005). Validity and reliability of screen II (seniors in the community: Risk evaluation for eating and nutrition, version II). *European Journal of Clinical Nutrition*, 59(10), 1149–1157. <https://doi.org/10.1038/sj.ejcn.1602225>
- Keller, H. H., & Trinca, V. (2023). Determinants of a decline in a nutrition risk measure differ by Baseline High Nutrition Risk Status: Targeting nutrition risk screening for frailty prevention in the Canadian Longitudinal Study on Aging (CLSA). *Canadian Journal of Public Health*, 114(4), 593–612. <https://doi.org/10.17269/s41997-023-00745-w>
- Keller, H. H., Hedley, M. R., & Wong Brownlee, S. (2000). The Development of Seniors in the Community: Risk Evaluation for Eating and Nutrition (SCREEN). *Canadian journal of dietetic practice and research : a publication of Dietitians of Canada = Revue canadienne de la pratique et de la recherche en dietetique : une publication des Dietetistes du Canada*, 61(2), 67–72.
- Keller, H., van der Schueren, M. A., Jensen, G. L., Barazzoni, R., Compher, C., Correia, M. I., Gonzalez, M. C., Jager-Wittenaar, H., Pirlich, M., Steiber, A., Waitzberg, D., & Cederholm, T. (2020). Global leadership initiative on malnutrition (GLIM): Guidance on validation of the operational criteria for the diagnosis of protein-energy malnutrition in adults. *Journal of Parenteral and Enteral Nutrition*, 44(6), 992–1003. <https://doi.org/10.1002/jpen.1806>
- Landi, F., Calvani, R., Tosato, M., Martone, A., Ortolani, E., Saveria, G., D'Angelo, E., Sisto, A., & Marzetti, E. (2016). Protein intake and muscle health in old age: From biological plausibility to clinical evidence. *Nutrients*, 8(5), 295. <https://doi.org/10.3390/nu8050295>
- Lang, P.-O., Michel, J.-P., & Zekry, D. (2009). Frailty syndrome: A transitional state in a dynamic process. *Gerontology*, 55(5), 539–549. <https://doi.org/10.1159/000211949>
- Laur, C., & Keller, H. (2017). Making the case for nutrition screening in older adults in primary care. *Nutrition Today*, 52(3), 129–136. <https://doi.org/10.1097/nt.0000000000000218>
- Laur, C., Carew, W., & Keller, H. (2020). Building nutrition into a falls risk screening program for older adults in family health teams in North Eastern Ontario. *Canadian Journal on Aging / La Revue Canadienne Du Vieillissement*, 40(1), 97–113. <https://doi.org/10.1017/s0714980819000850>

- Liang, H., Li, X., Lin, X., Ju, Y., & Leng, J. (2021). The correlation between nutrition and frailty and the receiver operating characteristic curve of different nutritional indexes for frailty. *BMC Geriatrics*, 21(1). <https://doi.org/10.1186/s12877-021-02580-5>
- Lorenzo-López, L., Maseda, A., de Labra, C., Regueiro-Folgueira, L., Rodríguez-Villamil, J. L., & Millán-Calenti, J. C. (2017). Nutritional determinants of frailty in older adults: A systematic review. *BMC Geriatrics*, 17(1). <https://doi.org/10.1186/s12877-017-0496-2>
- Meehan, M., & Penckofer, S. (2014). The Role of Vitamin D in the Aging Adult. *Journal of Aging and Gerontology*, 2(2), 60–71. <https://doi.org/10.12974/2309-6128.2014.02.02.1>
- Morrison, J. M., Laur, C. V., & Keller, H. H. (2019). Screen III: Working towards a condensed screening tool to detect nutrition risk in community-dwelling older adults using CLSA data. *European Journal of Clinical Nutrition*, 73(9), 1260–1269. <https://doi.org/10.1038/s41430-019-0411-3>
- Ni Lochlainn, M., Cox, N. J., Wilson, T., Hayhoe, R. P., Ramsay, S. E., Granic, A., Isanejad, M., Roberts, H. C., Wilson, D., Welch, C., Hurst, C., Atkins, J. L., Mendonça, N., Horner, K., Tuttielt, E. R., Morgan, Y., Heslop, P., Williams, E. A., Steves, C. J., ... Robinson, S. (2021). Nutrition and frailty: Opportunities for prevention and treatment. *Nutrients*, 13(7), 2349. <https://doi.org/10.3390/nu13072349>
- Norman, K., Haß, U., & Pirlich, M. (2021). Malnutrition in older adults—recent advances and remaining challenges. *Nutrients*, 13(8), 2764. <https://doi.org/10.3390/nu13082764>
- Pavlović, J. R., Maksimović, M., Klopunović, O. V., Vasilić, Z. S., Ivković, N. M., & Račić, M. N. (2020). Comparison of seniors in the community: Risk evaluation for eating and nutrition, version II and Mini Nutritional Assessment – short form in detecting nutritional risk among community-dwelling seniors in Bosnia and Herzegovina. *Public Health Nutrition*, 24(9), 2681–2688. <https://doi.org/10.1017/s1368980020002438>
- Pérez-Ros, P., Vila-Candel, R., & Martínez-Arnau, F. M. (2020). A home-based exercise program focused on proprioception to reduce falls in frail and pre-frail community-dwelling older adults. *Geriatric Nursing*, 41(4), 436–444. <https://doi.org/10.1016/j.gerinurse.2020.01.017>
- Power, L., Mullally, D., Gibney, E. R., Clarke, M., Visser, M., Volkert, D., Bardon, L., de van der Schueren, M. A. E., & Corish, C. A. (2018). A review of the validity of malnutrition screening tools used in older adults in community and healthcare settings – a manual study. *Clinical Nutrition ESPEN*, 24, 1–13. <https://doi.org/10.1016/j.clnesp.2018.02.005>

- Prado, C. M., Landi, F., Chew, S. T. H., Atherton, P. J., Molinger, J., Ruck, T., & Gonzalez, M. C. (2022). Advances in muscle health and nutrition: A toolkit for healthcare professionals. *Clinical Nutrition*, 41(10), 2244–2263. <https://doi.org/10.1016/j.clnu.2022.07.041>
- Public Health England. (2022). *Criteria for a population screening programme*. GOV.UK. <https://www.gov.uk/government/publications/evidence-review-criteria-national-screening-programmes/criteria-for-appraising-the-viability-effectiveness-and-appropriateness-of-a-screening-programme>
- Ramage-Morin, P. L., & Garriguet, D. (2013). Nutritional risk among older Canadians. *Health reports*, 24(3), 3–13.
- Ramage-Morin, P. L., Gilmour, H., & Rotermann, M. (2017). Nutritional risk, hospitalization and mortality among community-dwelling Canadians aged 65 or older. *Health reports*, 28(9), 17–27.
- Reber, E., Gomes, F., Vasiloglou, M. F., Schuetz, P., & Stanga, Z. (2019). Nutritional risk screening and assessment. *Journal of Clinical Medicine*, 8(7), 1065. <https://doi.org/10.3390/jcm8071065>
- Roberts, H. C., Lim, S. E., Cox, N. J., & Ibrahim, K. (2019). The challenge of managing undernutrition in older people with frailty. *Nutrients*, 11(4), 808. <https://doi.org/10.3390/nu11040808>
- Rockwood, K., & Mitnitski, A. (2007). Frailty in relation to the accumulation of deficits. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 62(7), 722–727. <https://doi.org/10.1093/gerona/62.7.722>
- Rubenstein, L. Z., Harker, J. O., Salva, A., Guigoz, Y., & Vellas, B. (2001). Screening for undernutrition in Geriatric Practice: Developing the short-form Mini-Nutritional Assessment (MNA-SF). *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(6). <https://doi.org/10.1093/gerona/56.6.m366>
- Rudnicka, E., Napierała, P., Podfigurna, A., Męczekalski, B., Smolarczyk, R., & Grymowicz, M. (2020). The World Health Organization (WHO) approach to healthy ageing. *Maturitas*, 139, 6–11. <https://doi.org/10.1016/j.maturitas.2020.05.018>
- Russell, J., Flood, V., Roachchina, E., Gopinath, B., Allman-Farinelli, M., Bauman, A., & Mitchell, P. (2012). Adherence to dietary guidelines and 15-year risk of all-cause mortality. *British Journal of Nutrition*, 109(3), 547–555.

- Sethar, W. A., Pitafi, A., Bhutto, A., Nassani, A. A., Haffar, M., & Kamran, S. M. (2022). Application of item response theory (irt)-graded response model (GRM) to Entrepreneurial Ecosystem Scale. *Sustainability*, 14(9), 5532. <https://doi.org/10.3390/su14095532>
- Serón-Arbeloa, C., Labarta-Monzón, L., Puzo-Foncillas, J., Mallor-Bonet, T., Lafita-López, A., Bueno-Vidales, N., & Montoro-Huguet, M. (2022). Malnutrition screening and assessment. *Nutrients*, 14(12), 2392. <https://doi.org/10.3390/nu14122392>
- ter Borg, S., Verlaan, S., Hemsworth, J., Mijnders, D. M., Schols, J. M., Luiking, Y. C., & de Groot, L. C. (2015). Micronutrient intakes and potential inadequacies of community-dwelling older adults: A systematic review. *British Journal of Nutrition*, 113(8), 1195–1206. <https://doi.org/10.1017/s0007114515000203>
- van Bokhorst-de van der Schueren, M. A. E., Guaitoli, P. R., Jansma, E. P., & de Vet, H. C. W. (2014). A systematic review of malnutrition screening tools for the Nursing Home Setting. *Journal of the American Medical Directors Association*, 15(3), 171–184. <https://doi.org/10.1016/j.jamda.2013.10.006>
- Vatanparast, H., Islam, N., Patil, R. P., Shafiee, M., & Whiting, S. J. (2020). Calcium intake from food and supplemental sources decreased in the Canadian population from 2004 to 2015. *The Journal of Nutrition*, 150(4), 833–841. <https://doi.org/10.1093/jn/nxz318>
- Villareal, D. T., Apovian, C. M., Kushner, R. F., & Klein, S. (2005). Obesity in older adults: Technical Review and position statement of the American Society for Nutrition and NAASO, the Obesity Society. *Obesity Research*, 13(11), 1849–1863. <https://doi.org/10.1038/oby.2005.228>
- Volkert, D., Kiesswetter, E., Cederholm, T., Donini, L. M., Eglseer, D., Norman, K., Schneider, S. M., Ströbele-Benschop, N., Torbahn, G., Wirth, R., & Visser, M. (2019). Development of a model on determinants of malnutrition in aged persons: A Manuel Project. *Gerontology and Geriatric Medicine*, 5, 233372141985843. <https://doi.org/10.1177/2333721419858438>
- Walston, J. D., Schmader, K. E., & Givens, J. (2023). Frailty. UpToDate. <https://www.uptodate.com/contents/frailty#>
- Wei, K., Nyunt, M.-S.-Z., Gao, Q., Wee, S.-L., Yap, K.-B., & Ng, T.-P. (2018). Association of frailty and malnutrition with long-term functional and mortality outcomes among community-dwelling older adults. *JAMA Network Open*, 1(3). <https://doi.org/10.1001/jamanetworkopen.2018.0650>

Weston, R., and Gore, P. A. Jr. (2006). A brief guide to structural equation modeling. *Couns. Psychol.* 34, 719–751.

Wijnhoven, H. A. H., Schilp, J., van Bokhorst-de van der Schueren, M. A. E., de Vet, H. C. W., Kruizenga, H. M., Deeg, D. J. H., Ferrucci, L., & Visser, M. (2012). Development and validation of criteria for determining undernutrition in community-dwelling older men and women: The short nutritional assessment questionnaire 65+. *Clinical Nutrition*, 31(3), 351–358.
<https://doi.org/10.1016/j.clnu.2011.10.013>

Young, Y., Frick, K. D., & Phelan, E. A. (2009). Can successful aging and chronic illness coexist in the same individual? A multidimensional concept of successful aging. *Journal of the American Medical Directors Association*, 10(2), 87–92. <https://doi.org/10.1016/j.jamda.2008.11.003>

APPENDIX 1 – SCREEN-14 TOOL



SCREEN-14 Rate your eating habits! Name: _____ Score: _____

- For each question, check **only one** box that describes you **best**.
- Your response should reflect your **typical eating habits**.

1a. Has your weight changed in the past 6 months?

- ☐ Yes, *I gained* more than 10 pounds.
☐ Yes, *I gained* 6 to 10 pounds.
☐ Yes, *I gained* about 5 pounds.
☐ No, my weight stayed within a few pounds.
☐ Yes, *I lost* about 5 pounds.
☐ Yes, *I lost* 6 to 10 pounds.
☐ Yes, *I lost* more than 10 pounds.
☐ I don't know how much I weigh or if my weight has changed.

1b. Have you been trying to change your weight in the past 6 months?

- ☐ Yes.
☐ No.
☐ No, *but it changed anyway*.

1c. Do you think your weight is ...?

- ☐ More than it should be.
☐ Just right.
☐ Less than it should be.

2. Do you skip meals?

- ☐ Never or rarely.
☐ Sometimes.
☐ Often.
☐ Almost every day.

3. Do you limit or avoid certain foods?
- ₄ ☐ I eat most foods.
- ₂ ☐ I limit some foods and I am managing fine.
- ₀ ☐ I limit some foods and I am finding it difficult to manage.
4. How would you describe your appetite?
- ₄ ☐ Very good.
- ₃ ☐ Good.
- ₂ ☐ Fair.
- ₀ ☐ Poor.
5. How many pieces or servings of vegetables and fruit do you eat in a day?
Vegetables and fruit can be canned, fresh, or frozen.
- ₄ ☐ Five or more.
- ₃ ☐ Four.
- ₂ ☐ Three.
- ₁ ☐ Two.
- ₀ ☐ Less than two.
6. How often do you eat meat, eggs, fish, poultry, tofu, dried peas, beans, lentils, nuts, or nut butters?
- ₄ ☐ Two or more times a *day*.
- ₃ ☐ One to two times a *day*.
- ₁ ☐ Once a *day*.
- ₀ ☐ Less than once a *day*.
7. How often do you have milk, soy beverages, or milk products such as cheese, yogurt, or kefir?
- ₄ ☐ Three or more times a *day*.
- ₃ ☐ Two to three times a *day*.
- ₂ ☐ One to two times a *day*.
- ₁ ☐ Usually once a *day*.
- ₀ ☐ Less than once a *day*.

8. How much fluid do you drink in a day?
Examples are water, tea, coffee, herbal drinks, juice, and soft drinks, but NOT alcohol.

- ₄ ☐ Eight or more cups.
₃ ☐ Five to seven cups.
₂ ☐ Three to four cups.
₁ ☐ About two cups.
₀ ☐ Less than two cups.

9. Do you cough, choke or have pain when swallowing food OR fluids?

- ₄ ☐ Never.
₃ ☐ Rarely.
₁ ☐ Sometimes.
₀ ☐ Often or always.

10. Is biting or chewing food difficult for you?

- ₄ ☐ Never.
₃ ☐ Rarely.
₂ ☐ Sometimes.
₀ ☐ Often or always.

11. Do you use commercial meal replacements or supplements?

Examples are shakes, puddings, or energy bars.

- ₄ ☐ Never or rarely.
₂ ☐ Sometimes.
₀ ☐ Often or always.

12. Do you eat one or more meals a day with someone?

- ⁰ ☐ Never or rarely.
² ☐ Sometimes.
³ ☐ Often.
⁴ ☐ Almost always.

13a. Who usually prepares your meals?

- ☐ I do.
☐ I share my cooking with someone else.
☐ Someone else cooks most of my meals.

13b. Which statement best describes meal preparation for you?

- ⁴ ☐ I enjoy cooking most of my meals.
² ☐ I *sometimes* find cooking a chore.
⁰ ☐ I *usually* find cooking a chore.
⁴ ☐ I'm *satisfied* with the quality of food prepared by others.
⁰ ☐ I'm *not satisfied* with the quality of food prepared by others.

14. Do you have any problems getting your groceries?

Problems can be poor health or disability, limited income, lack of transportation, weather conditions, or finding someone to shop.

- ⁴ ☐ Never or rarely.
² ☐ Sometimes.
¹ ☐ Often.
⁰ ☐ Always.

Thank you for telling us about your eating habits.

For further details on SCREEN, visit: www.olderadultnutritionscreening.com
If you are an older adult completing this and want more information, please bring the results your primary healthcare provider.

APPENDIX 2 – RECRUITMENT MATERIAL

Email Recruitment for both Rounds of Delphi

Study Title: Confirming and Expanding SCREEN for a frail population: a DELPHI study

First round of DELPHI [sent from H Keller email]

EMAIL Subject line: INVITATION to Expert consensus group for SCREEN and frail populations

This email is being sent on behalf of the researchers.

You have been identified by the investigators of this study (Professor Heather Keller, Meagan Jackson, Sharon Kirkpatrick, and Alex Wong of the University of Waterloo) as someone who has made contact with Professor Keller about SCREEN or used SCREEN (Seniors in the Community Risk Evaluation for Eating and Nutrition) in your practice and/or research to identify nutrition risk of older adults living in the community. We are conducting a DELPHI study to determine expert opinions on if and how we should revise SCREEN to ensure we are identifying the nutrition risk factors common to older adults living with frailty in the community.

A DELPHI study usually involves two or three rounds of focused questions to gain insight from experts and build consensus on a topic.

What is being asked of me:

The DELPHI survey will be conducted online. We anticipate that the first round of the survey will take approximately 20 minutes to complete. You will be provided approximately a two to three week period to complete each round of questions. If you need more time, we can extend this for you. We anticipate that the 2nd and if necessary, 3rd round of questions will be shorter than the first. We will continue to send out invitations for all rounds regardless of your participation in a prior round. If you wish to not receive these invitations, please email the graduate student on this project at Meagan.jackson@uwaterloo on this project to indicate you wish to no longer receive further emails.

We will ask demographic questions such as gender, age group, race, ethnicity, region of the world you work/live in and how you have used SCREEN in the past in order to describe our experts.

Attached is an **information letter** that provides further details on this DELPHI study.

Please note that further communications around this study will be conducted by the graduate student Meagan Jackson to keep your identity confidential from the other investigators.

Please click the following link [link to be inserted here] to be directed to an external platform, Qualtrics, to complete the online survey.

Please complete this round of the DELPHI by March 19th 2023.

If you need more time to complete this survey, please email the graduate student Meagan Jackson (meagan.jackson@uwaterloo.ca) to receive an extension.

If you have any questions, please contact Professor Keller at hkeller@uwaterloo.ca or 519 888 4567 ext 41761

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB#44963).

Thank you in advance for your interest in this study!

Second Round of DELPHI {Sent from M Jackson Email}

EMAIL Subject line: Round 2 survey: Expert consensus group for SCREEN and frail populations

Thank you for participating in the DELPHI survey being used to determine your expert opinion on how we should revise and improve SCREEN to capture the nutrition risk of frail older adults living in the community.

We are now at the 2nd round of the survey. This series of questions is shorter than the last version you completed. We expect the survey will take approximately 15 minutes to complete.

The link for this round of the survey is here XXXXX

Please complete this round by May 5th 2023.

If you need more time to complete this survey or would like to be removed from the expert invitation list, please let me know by responding to this email (meagan.jackson@uwaterloo.ca).

If you have any questions about the study in general, please contact Professor Keller at hkeller@uwaterloo.ca or 519 888 4567 ext 41761

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB#44963).

Thank you very much for your continued interest in improving SCREEN!

APPENDIX 3 – STUDY INFORMATION LETTER AND CONSENT INDICATION

Information Letter



FACULTY OF HEALTH | Department of Kinesiology and Health Sciences
519-888-4567 | fax 519-888-4666 | uwaterloo.ca/kinesiology-health-sciences

Title of the study: Confirming and Expanding SCREEN for a frail population: a DELPHI study

Investigators: Professors Heather Keller, Sharon Kirkpatrick and Alex Wong
(University of Waterloo)

Student investigator: Meagan Jackson (University of Waterloo)

This letter explains what the study is about, possible risks and benefits, and your rights as a research participant. If you have any questions about the study, please contact Heather Keller at hkeller@uwaterloo.ca

What is the study about?

You are invited as an expert to help us determine if and how SCREEN (Seniors in the Community Risk Evaluation for Eating and Nutrition) should be revised to better capture the nutrition risk of older adults who are frail. To determine your expert opinion, we are conducting a DELPHI survey. DELPHI surveys involve a small number of experts (<30) and typically require two or three rounds of questionnaires to determine consensus on an issue. For this study, we hope to confirm what items on SCREEN are most relevant for frail older adults, if new questions are required and what the content of these questions may be.

Who should participate?

Experts who have used SCREEN in their clinical practice or research have been invited to participate. We anticipate 2 or 3 rounds of questions for this DELPHI study. We will email you the links for the subsequent questionnaires when they are ready and give you

a deadline of 2-3 weeks for completion. If you need more time to complete the survey, please let us know. If you wish to stop receiving invitations to participate in the survey, you can let the graduate student investigator know by email at m23jackson@uwaterloo.ca

What does participation involve?

Participants are invited to complete up to three short (~ 15- 20 minutes) online questionnaires on SCREEN. The first survey will be slightly longer than subsequent ones at about 20. We will ask demographic questions such as gender, age group, race/ethnicity, region of the world you live in and how you have used SCREEN in the past in the first questionnaire. This information will help us describe our experts.

Survey questions are focused on your thoughts and opinions as an expert who has used SCREEN in the past for clinical practice or research. For example, should questions be removed to help focus SCREEN further for frail older adults, or are new questions required? Open text responses will be used to help us develop the questions for the subsequent rounds. When providing your consent to the study, we will also request that you provide consent for the use of any quotes from these open text responses, to be used in presentations or manuscripts resulting from this research.

If we find we have consensus on most or all aspects on this issue after the 2nd round, there will not be a third round of questions.

The online survey will be conducted in English.

Is participation in this study voluntary?

Participation in this study is completely voluntary and you may stop at any time. If you decide to stop once the survey has begun, please exit out of the program by closing the browser window or your internet browser. Demographic questions will have a “prefer not to answer” option. Once your answers are submitted, data cannot be withdrawn as it is de-identified.

After this information letter is an opportunity for you to indicate your consent to participate in the study and also to provide consent for the use of quotes from your open text responses. By providing your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

Will I receive anything for participating in this study?

We will be happy to share with you the results of this DELPHI study.

What are the possible benefits of this study?

This study will not provide any personal benefit to you. The information collected from this study will aid in revising SCREEN to be a better tool for targeting nutrition risk in frail older adults living in the community.

What are the risks associated with this study?

As a person who has used SCREEN in the past, you may know or have work relationships with the co-investigators. To prevent any concern you may have about the co-investigators treating you differently as a result of completing or not completing the survey, we are not collecting identifying information such as your email or name on the survey. All data are de-identified. Further, the graduate student Meagan Jackson will be the only individual interacting with the data and summarizing this for the co-investigators. If you decide to stop participating after the first questionnaire, only the graduate student will know this. To further ensure confidentiality, this student will remove all demographic information from survey responses and put these in a separate file for descriptive analyses.

What are the risks associated with an online survey?

You will be completing the study through an online survey operated by Qualtrics. Qualtrics has implemented technical, administrative, and physical safeguards to protect the information from loss, misuse, and unauthorized access, disclosure, alteration, or destruction. However, no Internet transmission is ever fully secure or error free.

Please Note: We do not collect or use internet protocol (IP) addresses or other information which could link your participation to your computer or electronic device.

Will my identity be known to others?

As survey responses are de-identified, you will not be identifiable from your submitted questionnaires. We will report the number of experts by their gender, ethnicity/race, age group, and region of the world, as well as by how they have used SCREEN in the past.

Any quotes that may be used from open text responses in results presentations or manuscripts will be identified by a participant number code.

Will my information be kept confidential?

Survey responses are de-identified, they are not linked to your email or name. Data collected through this study will be kept for a period of at least 7 years on a password protected server at the University of Waterloo.

Who is sponsoring/funding this study?

This study is funded by the National Research Council of Canada as part of project led by Dr. Alex Wong at the University of Waterloo.

How can I find out about the results from this study?

You may obtain information about the final results of this study from Professor Keller by emailing hkeller@uwaterloo.ca

Has this study received ethics clearance?

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB #44963). If you have questions for the Board, please contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or reb@uwaterloo.ca.

Who should I contact if I have questions regarding my participation in the study?

If you have any questions regarding this study please contact Professor Heather Keller hkeller@uwaterloo.ca or 519 888 4567 ext 41761.

Sincerely,



Heather Keller RD, PhD, FDC FCAHS
Professor and
Schlegel-UW Research Chair Nutrition & Aging



Consent Forms

Electronic Consent

I agree to participate in the research study and complete this online survey. I understand the purpose and nature of this study and I am participating voluntarily. I understand that I can withdraw from the study at any time, without any penalty or consequences. If I have submitted my answers, I understand that these cannot be withdrawn as they are de-identified.

Clicking on the “I agree” button below indicates that you have read the above information and you voluntarily agree to participate. By agreeing to participate in the study you are not waiving your legal rights or releasing the investigator(s) or involved homes(s) from their legal and professional responsibilities. If you decide to discontinue participation once the survey has begun, please exit out of the program by closing this window or your internet browser.

☐ I agree to participate

☐ I do not want to participate

I understand that some of the open text comments may be used verbatim for research presentations or manuscripts, but that these will be de-identified by using a participant number. By clicking on the “I provide consent” button below I am indicating that I am aware of this potential for use of quotes based on my data and provide my consent.

☐ I provide consent for my quotes to be used for research publications

☐ I do not want my open text material used for quotes in research publications

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APPENDIX 4 – STUDY SURVEYS

Delphi Questions Round 1

Question 1

How confident are you that the current SCREEN-14 can identify nutrition risk in frail older adults living in the community (e.g., retirement homes, living in their own home) (1=not confident, 7= very confident)

Comments:

Question 2

For each of the SCREEN-14 questions/sub-questions below, please indicate if you think this question is unnecessary, somewhat necessary, or absolutely necessary to identify nutrition risk in frail older adults. [matrix question with responses as column dial buttons; SCREEN questions as rows]

Comments:

Question 3

For each of the SCREEN-14 questions/sub-questions below, please indicate if you think this question would be triggered (i.e., the person will receive a low score, indicating risk for this item) in frail older adults. [matrix question with responses as column dial buttons; SCREEN questions as rows]

Comments:

Question 4

To what extent do you think the current questions on high protein foods and use of milk products or fortified soy beverages adequately determine potential risk in frail older adults due to low protein intake?

(1= not adequate, 7= very adequate)

Comments:

Question 5

To what extent do you think the current question on use of milk products or fortified soy beverages adequately determines potential risk in frail older adults due to low calcium intake?

(1= not adequate, 7= very adequate)

Comments:

Question 6

To what extent do you think the current question on use of milk products or fortified soy beverages adequately determines potential risk in frail older adults due to low vitamin D intake?

(1= not adequate, 7= very adequate)

Comment:

Question 7

If we are aiming to ensure that SCREEN identifies nutrition risk in older adults who are frail, are there any questions you would change?

Open text box

Question 8

If we are aiming to ensure that SCREEN identifies nutrition risk in older adults who are frail, are there any questions you would add to this screener? For example, would a vitamin supplement question help to determine vitamin D intake?

Open text box

Do you have any further comments about nutrition risk and frailty in community living older adults?

Open text box

Demographic questions

Please respond to the following questions to help us understand the characteristics of our expert group. Please note that your responses to these questions will **not** be linked with your responses to the prior questions on SCREEN-14. If you prefer not to answer, please use that option.

I use SCREEN in (check all that apply)

My clinical practice with older adult clients

My research

As part of managing others to conduct nutrition screening

I have not yet used SCREEN in research or practice

Other, Please describe

Prefer not to answer

What region do you work in?

Canada

Other North America

South America

Central America

Caribbean

Central and South Asia

Northeastern Asia

Southeastern Asia

Australia and Oceania

Europe

Middle East

Africa

Prefer not to answer

What age group do you belong to?

☐ 20-25 years

☐ 26-39 years

☐ 40- 55 years

- 56+ years
- Prefer not to answer

What is your gender?

- Man/Transgender man
- Woman/Transgender Woman
- Gender Variant / Non-conforming/Non-binary
- Not listed [open text response]
- Prefer not to answer

Which of the following best describes your racial or ethnic background? [select all that apply]

- Asian - East (e.g., Chinese, Japanese, Korean)
- Asian - South (e.g., Indian, Pakistani, Sri Lankan)
- Asian - Southeast (e.g., Malaysian, Filipino, Vietnamese)
- Black - African (e.g., Ghanaian, Kenyan, Somali)
- Black - Caribbean (e.g., Barbadian, Jamaican)
- Black - North American (e.g., Canadian, American)
- First Nations
- Indian - Caribbean (e.g., Guyanese with origins in India)
- Indigenous/Aboriginal not included elsewhere
- Inuit

- Latin American (e.g., Argentinean, Chilean, Salvadorian)
- Métis
- Middle Eastern (e.g., Egyptian, Iranian, Lebanese)
- White - European (e.g., English, Italian, Portuguese, Russian)
- White - North American (e.g., Canadian, American)
- Prefer to self-describe as _____
- Prefer not to answer
- Do not know

Delphi Questions Round 2

First page of the Delphi Questionnaire #2

Thank you for helping us to refine the SCREEN (Seniors in the Community Risk Evaluation for Eating and Nutrition) nutrition risk questionnaire. The first round of the Delphi survey completed in March, 2023 provided valuable insights on how we can refine SCREEN to identify nutrition risk in frail older adults. This second and last Delphi survey will help us to confirm these refinements.

From the first round of the Delphi survey, we have identified a subset of SCREEN items as most relevant when determining nutrition risk in a frail older adult. We will ask you to confirm your agreement on these items. We will also ask you to confirm some new questions that were recommended.

Some suggestions were outside of the scope of the current project. Although we are grateful for all the feedback provided, we will not be seeking consensus on those ideas at this time.

Here is a link to the SCREEN-14 questionnaire if you would like to review this nutrition risk tool before answering the following questions.

Question 1

Below is a minimum set of SCREEN items that most round 1 respondents indicated should be included in a shorter version of SCREEN to identify nutrition risk in frail older adults.

Please indicate if you think each item should be included in or excluded from a minimum set of SCREEN questions to identify nutrition risk in frail older adults.

Question 2

Below are the remaining SCREEN-14 questions that were not selected as absolutely necessary by a high proportion of round 1 respondents.

Please indicate if you think each item should be included in or excluded from a minimum set of SCREEN questions to identify nutrition risk in frail older adults.

Question 3

Some participants identified that a question on vitamin D Supplement intake would be a useful addition to a shorter version of SCREEN to identify nutrition risk in frail older adults.

For identifying nutrition risk in frail older adults, do you think a new question on vitamin D supplementation in SCREEN is necessary ... (on a scale of 1-7)

Question 4

Some participants identified that a question on calcium supplement intake would be a useful addition to a shorter version of SCREEN to identify nutrition risk in frail older adults.

For identifying nutrition risk in frail older adults, do you think a new question on calcium, supplementation in SCREEN is necessary ... (on a scale of 1-7)

Question 5

Below are two questions [A) and B)] asking about vitamin D supplementation. Please identify the one you prefer in the box below and suggest any changes in wording.

A) If you take a daily supplement with vitamin D, what is the dose?

₄ ☐ more than 1000IU.

₃ ☐ 1000IU.

₂ ☐ 400- 999IU

₁ ☐ less than 400IU

₀ ☐ do not take a vitamin D supplement

B) Do you take a Vitamin D supplement?

₄ ☐ Yes.

₁ ☐ Not sure.

₀ ☐ No.

Question 6

Below are two questions [A) and B)] asking about calcium supplementation. Please identify the one you prefer in the box below and suggest any changes in wording.

A) If you take a daily supplement with calcium, what is the dose?

₄ ☐ more than 800 mg

₃ ☐ 501- 799 mg

₂ ☐ 250- 500 mg

₁ ☐ less than 250 mg

₀ ☐ do not take a supplement with calcium

B) Do you take a calcium supplement?

₄ ☐ Yes.

₁ ☐ Not sure.

₀ ☐ No.

Question 7

Do you have any further comments about using SCREEN to identify nutrition risk in frail older adults?

Open text box