Validation of Self-application-based Malnutrition and Limited Mobility Screening Tools Compared with Standard Diagnostic Tools in Older Adults

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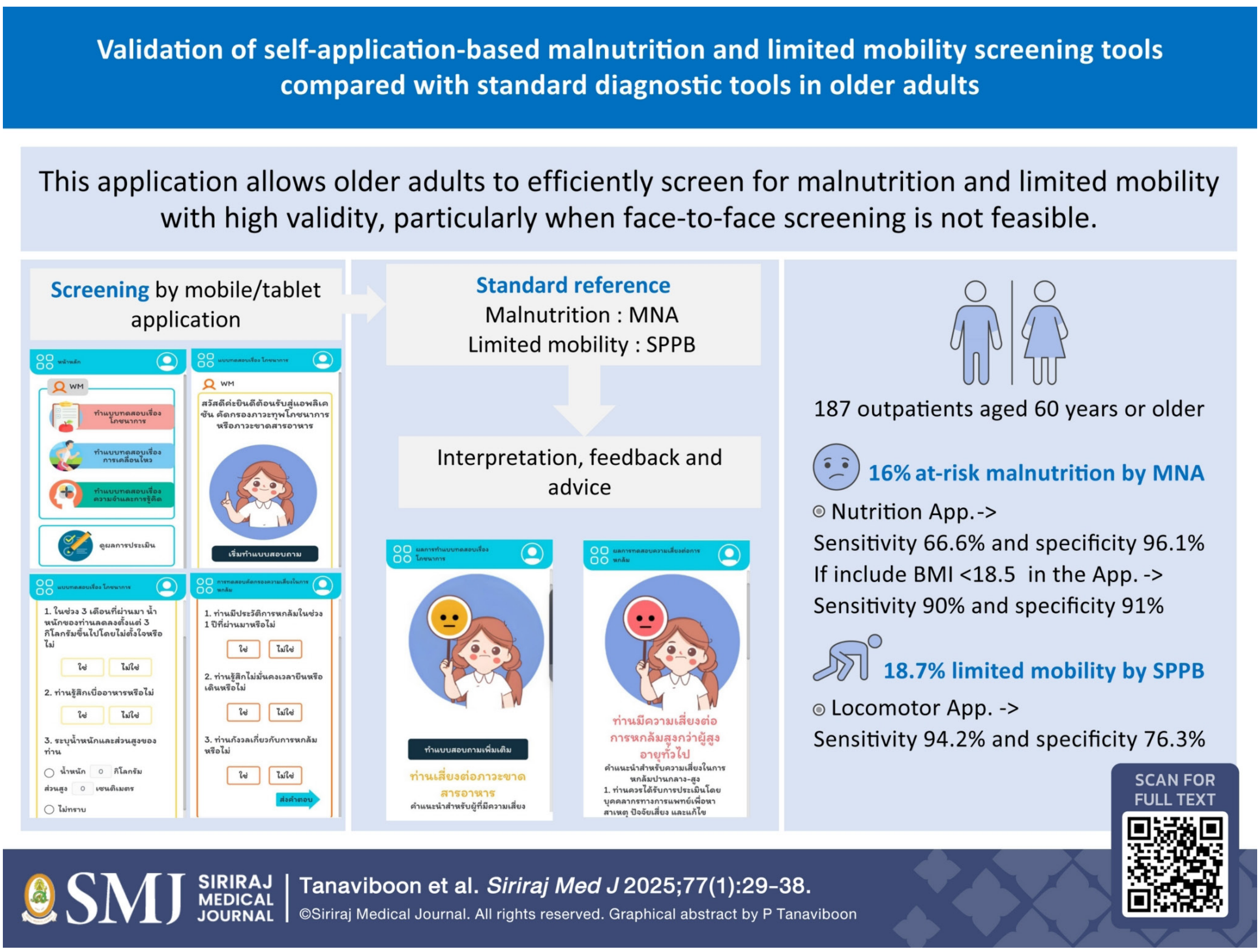

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ABSTRACT

Objective: To validate application screening tools against face-to-face standard tools (the Mini Nutritional Assessment (MNA) and Short Physical Performance Battery test (SPPB)) in older adults.

Materials and Methods: A mobile or tablet application was developed based on user interfaces and experiences. Outpatients aged 60 years and over were tested with this tool. We used 2 questions from the WHO-ICOPE algorithm and 3 questions from the STEADI algorithm to screen for at-risk malnutrition and limited mobility, respectively. The MNA and SPPB were used to detect malnutrition and limited mobility, respectively, to test their validity.

Results: The study involved 187 participants, 16% of whom were diagnosed with at-risk malnutrition by the MNA and 18.7% of whom had limited mobility according to the SPPB. The sensitivity and specificity of the malnutrition application tool were 66.6% and 96.1%, respectively. When BMI < 18.5 was combined in the application, the sensitivity and specificity were 90% and 91%, respectively. For limited mobility, the sensitivity and specificity of the application were 94.2% and 76.3%, respectively. The majority of participants rated the application for easy understanding as «excellent» (65%) and rated their confidence in their ability to use the application by themselves as "excellent" (70%).

Conclusion: The application is an age-friendly, time-saving tool that can be used when face-to-face screening is difficult with good validity.

Keywords: Screening; Application; Older adults; Malnutrition; Locomotor capacity; Intrinsic capacity; Limited mobility; WHO-ICOPE (Siriraj Med J 2025; 77: 29-38)

INTRODUCTION

Populations worldwide are transitioning toward an aging society, and the trend is rapidly increasing. In October 2017, the World Health Organization (WHO) released "Integrated care for older people: Guidelines on community-level interventions to manage declines in intrinsic capacity".[1] The guidelines include care for various aspects of intrinsic capacity, including vitality, locomotor, psychological, visual, hearing, and cognitive capacity.[1]

"Vitality" refers to the physiological factors related to locomotor capacity, encompassing balance and energy expenditure within the body. One significant factor contributing to reduced vitality among older adults is malnutrition,[1,3] a problem affecting up to 10% of the population aged 65 and above;[2] its impact on quality of life is substantial and affects disability rates, hospitalization duration, mortality rates, and healthcare costs.[3-4]

Locomotor capacity refers to an individual's physical ability to move from one place to another. Mobility is a crucial factor in healthy aging, developing disability, and preventing dependence on others.[1] Limited mobility is common among older adults, leading to difficulties in movement, cognitive decline, and social issues. Additionally, limited mobility can result in dependency, disabilities, physical injuries, hospitalization, and an increased length of stay.[11,12] Screening for limited mobility and providing care to improve flexibility are essential for achieving a good quality of life.[1]

As mentioned, assessing nutritional status and locomotor capacity is crucial. Early screening for malnutrition and limited mobility, followed by prompt assessment and treatment, can lead to positive outcomes.[1] Screening tools should be rapid, user-friendly, cost-effective, standardized, and valid.[5] Various types of screening tools have been developed to assess intrinsic capacity; however, they have limitations such as the need for face-to-face assessments, time-consuming procedures, and difficulty reaching individuals who are far away and cannot easily access healthcare facilities. Furthermore, many tests require long evaluation times. For example, the SPPB assessment takes an average of approximately 10–15 minutes.[11] In the present era of advanced medical technology, electronic applications are being increasingly used for screening to assess nutritional status more effectively. The benefits include remote access without the need to visit a hospital, which is particularly advantageous during the COVID-19 pandemic, as it helps reduce face-to-face contact. Researchers have aimed to develop electronic applications to screen for malnutrition and limited mobility among Thai older adults, thus increasing the chance of accessing diagnostic tests and interventions to improve their physical capabilities. Moreover, if malnutrition or decreased mobility is detected, basic self-care instructions and guidance on seeking medical attention at hospitals, especially for high-risk individuals, are provided. However, tool development requires validity evaluation and possibility of self-screening.

MATERIALS AND METHODS

This research was approved by the Ethics Committee for Research in Human Subjects, Faculty of Medicine, Siriraj Hospital, Mahidol University, Thailand. The approval number is 344/2566 (IRB3). The certificate of approval is Si 463/2023. This study was subsequently conducted from 2023–2024 and is classified as observational clinical research (diagnostic research). The older adults who came to Siriraj Hospital, the quaternary care medical center in Thailand, were randomly selected using the consecutive sampling method. Researchers conducted patient screening using the Eligibility Criteria Checklist before obtaining consent from participants or their relatives.

The inclusion criteria included outpatients aged 60 and older who could communicate, read Thai and answer questions on mobile or tablet applications. Exclusion criteria included those with visual or hearing impairments that impeded the application or standard tests, disabilities affecting the use of the application or SPPB, and dyspnea (functional classes III–IV). Individuals who requested not to be contacted or do not wish to disclose their medical records were excluded, as were those with prior evidence of severe neuropsychiatric diseases affecting communication, such as severe dementia with behavioral and psychological symptoms of dementia (BPSD) or schizophrenia. Inpatient older adults were also excluded. Participants or their legal representatives had the right to withdraw from the research at any time without consequences; this ensured that participation was voluntary and that participants could drop out at their discretion. Additionally, participants who did not cooperate in completing the questionnaire or testing via electronic tools or the standard test were excluded from the study.

All participants were provided with detailed explanations and asked for consent before they participated in the study. General patient information, including sex, age, occupation, level of education, primary caregiver, preexisting conditions, current medications, history of alcohol consumption, history of surgery, history of hearing and vision impairment, oral health status and denture usage, functional status, physical activity, history of falling, gait aid usage, and oral nutritional supplementation, was also collected from the electronic medical record system and self-reporting. Participants underwent screening for malnutrition and mobility impairment via application screening tools, with participants using the tools themselves; afterward, trained medical personnel evaluated them for the MNA and SPPB. The user satisfaction and experience were also investigated. Statistical analysis was conducted on all collected data. Appendix: Figure 1 illustrates the flow chart of the validation process.

Malnutrition

Standard tool: The current gold standard for diagnosing malnutrition is the GLIM criteria, which comprises screening and assessment of nutritional status.[9] According to the MaNuEL study, the MNA can be used as a standard reference tool for evaluating the validity of nutritional screening instruments;[6,8] these are considered 'semigold' reference standards and can be used as substitutes for the gold standard in certain cases, such as for measuring changes in body composition.[6] The full form of the Mini Nutritional Assessment (MNA)[10,19] comprises both screening and assessment components for nutritional status, including measurements via anthropometry;[5] notably, it bears similarities to the GLIM criteria used for diagnosing malnutrition.[10] Additionally, various studies have shown that the MNA performs well in community-dwelling older adults.[5,8,10] Consequently, researchers have chosen to utilize the MNA to assess the validity of electronic screening programs for at-risk malnutrition in elderly individuals. The cutoff point is below 24 points.

Screening tool: We use a tool that is simple and concise, making it easy for older adults to use. To screen for at-risk malnutrition, we used the WHO-ICOPE 2 questions (unintentional weight loss >3 kg over the last 3 months, OR appetite loss).[1] Appendix: Figure 2 illustrates the self-application-based malnutrition screening tool. In previous trials when we developed this tool, there were limited data of its validity, but now there is a study published. However, the study was not in application-based self-assessment and has never been conducted in Thailand. In a cross-sectional study of the ICOPE screening tool in China, the sensitivity was 51.3%. However, the specificity was 94.7%, which indicates a high validity. When included a BMI below 20 kg/m^2 provided better sensitivity.[6] Thus, we included BMI in the application and separated the calculation of the statistic of whether or not to include BMI. The screening was considered positive when the participant answered yes to one of the two questions.

Locomotor capacity impairment (Limited mobility)

Standard tool: Several tools have been used to evaluate senior people's mobility and balance.[11,20-22] However, there is currently no clear consensus on which tool should be the primary assessment method, depending on the aspect that we want to evaluate.[11] The SPPB is a tool used to assess gait, balance, and endurance in older adults, both in research and clinical settings.[26] The SPPB can predict disability, falls, activities of daily living (ADL), limited mobility, and hospitalization rates.[10,25] Studies have consistently reported that the SPPB is accurate and reliable for assessing mobility capacity in older adults across various environments, with minimal environmental impact on measurement reliability.[13-14] Researchers use the SPPB as a standard assessment tool for evaluating the validity of electronic screening programs for limited mobility. A cutoff of less than 10 points is used to detect locomotor capacity impairment or limited mobility.

Screening tool: To screen for limited mobility or locomotor capacity impairment that causes an increase in fall risk, we used the first-step 3-key questions of the STEADI algorithm (feel unsteady when standing or walking, worry about falling, or have fallen in the past year).[35,36] In the prospective cohort study of older adults living in Nakhon Ratchasima, Thailand, the sensitivity of the first step 3-key questions by clinicians was 93.9%, and the specificity was 88%.[37] The screening was considered positive when the participant answered yes to one of the three questions. Appendix: Figure 3 illustrates the self-application-based limited mobility screening tool (limited mobility).

User acceptance testing

We conducted interviews with participants to rate the application in terms of two aspects: ease of understanding and confidence in the use of the application. For ease of understanding, the participants rated the application on a scale of 1- to 5, with 1 being poor, 2 being fair, 3 being average, 4 being good, and 5 being excellent. Similarly, for their confidence in using the application by themselves, the participants provided ratings on the same 1- to 5 scale, indicating their level of confidence from poor to excellent. These ratings provided valuable insights into the user experience and overall satisfaction with the application.

Sample size calculation

Tool: Self-application-based malnutrition screening tool.

The sample size for this study was calculated based on the sensitivity and specificity values obtained from previous studies. Screening for malnutrition has demonstrated a sensitivity of 73% and a specificity of 84%.[23] The pooled prevalence of at-risk malnutrition is reported to be 42.6%.[24] To estimate the required sample size for each group, the principle of estimating a single proportion with a margin of error (d=0.10) is applied. This method ensures that the sample size is sufficient to accurately reflect the sensitivity and specificity of the malnutrition screening tool within an acceptable margin of error. Therefore, the estimated total sample size required for at-risk malnutrition in this study was 178 participants.

Tool: Self-application-based limited mobility screening tool.

The sample size for locomotor capacity impairment was calculated based on the sensitivity and specificity of the ICOPE tool from previous studies. For individuals with limited mobility, the ICOPE tool has shown a sensitivity of 85% and a specificity of 92.8%, with a prevalence of limited mobility of 35%.[25] To calculate the required sample size for each group, the principle of estimating a single proportion with a margin of error (d=0.10) was applied. The estimated total sample size required for the study was 140 participants.

Thus, the total sample size was initially calculated as 178 participants. A possible 5% data loss rate must be taken into consideration when adjusting the sample size. Consequently, an adjusted total sample size of 187 participants was needed for the investigation.

Statistical analysis

We analyzed the outcome measurements for this study to confirm the validity of the application screening tools in detecting malnutrition and locomotor capacity impairment, comparing them with the standard tools MNA and SPPB. We present descriptive data in terms of percentages, means, and standard deviations to provide participant demographic data. The validity of the self-application-based malnutrition and limited mobility screening tools was evaluated by sensitivity, specificity, positive and negative predictive values, and likelihood ratios. The accuracy was also investigated. User satisfaction and experience were assessed by analyzing participants' ratings of easy understanding of and confidence in their use of the application. We reported these ratings as percentages. The data were analyzed using SPSS version 18.0 (SPSS Inc., PASW Statistics for Windows, Chicago, IL, USA).

RESULTS

A total of 187 people participated in the study (mean age, 69.8±7 years). Appendix: Figure 4 illustrates the age distribution of the participants. Thirty (16%) patients were diagnosed with at-risk malnutrition by the MNA, and 35 (18.7%) were diagnosed with limited mobility by the SPPB. The baseline characteristics are described in the Table 1 & 2. The validity of the application for

TABLE 1. Demographic data: Nutritional status.

Parameter	Normal nutritional status (n=157)	At risk malnutrition/ Malnutrition (n=30)	Total (n=187)
Age (mean±SD)	70±6.9	69±7.5	70±7
Female, n (%)	101 (64.3)	24 (80)	125 (66.8)
Education, years (mean±SD)	12±4.7	11±5	12±4.7
Living alone, n (%)	22 (14)	7 (23.3)	29 (15.5)
Financial problem, n (%)	9 (5.7)	2 (6.7)	11 (5.9)
Oral problem, n (%)	119 (75.8)	26 (86.7)	145 (77.5)
Denture use, n (%)	64 (41)	15 (50)	79 (42.2)
Cognitive impairment, n (%)	15 (9.5)	2 (6.7)	17 (9.1)
Malignancy, n (%)	12 (8)	5 (14.7)	17 (9.2)
Stroke, n (%)	6 (3.8)	1 (3.3)	7 (3.7)
CAD, n (%)	8 (5.1)	1 (3.3)	9 (4.8)
DM, n (%)	39 (25)	5 (16.7)	44 (23.7)
Osteoporosis, n (%)	7 (4.5)	5 (16.7)	12 (6.4)
Polypharmacy ≥ 5 drugs, n (%)	43 (27.4)	6 (20)	49 (26.2)
History of fall in past 1 yr, n (%)	20 (12.7)	4 (13.3)	24 (12.8)
Oral nutritional supplementation, n (%)	19 (12.1)	7 (23.3)	26 (13.9)
Gait aid use, n (%)	3 (1.9)	2 (6.7)	5 (2.6)
BMI, kg/m^2 (mean±SD)	24.2±4.1	18.6±2.9	23.3±4.4
Locomotor capacity impairment, n (%)	28 (17.9)	7 (23.3)	35 (18.7)

detecting malnutrition and limited mobility is shown in the Table 3. Validation of the application of Malnutrition compared with that of the MNA. If a BMI < 20, which is used for diagnosing malnutrition in older adults, was included in the application, the sensitivity and specificity increased to 100% and 81.5%, respectively. When the ROC curve was used to find the best cutoff point, a BMI of 19.38 provided the best results. For limited mobility applications that use the first-step 3-key questions of the STEADI algorithm, the sensitivity and specificity were 94.2% and 76.3%, respectively. For each question, "feeling unsteady when standing or walking" yields the best result. Table 4 shows the validation of the limited mobility application compared with SPPB.

In terms of user satisfaction and experience, the participants rated the application for easy understanding as "excellent" 65%, "good" 32.5%, or "average" 2.5%. They rated their confidence in their ability to use the application by themselves as "excellent" 70%, "good" 25%, or "average" 5%. The time to complete the application averaged less than 2 minutes. Appendix: Figure 5 illustrates user satisfaction with the application (easily understanding point, %), Appendix: Figure 6 illustrates user satisfaction with the application (confidence in their ability to use the application by themselves, %).

DISCUSSION

To date, few studies have included mobile or tablet applications in the process of screening for malnutrition or limited mobility in Thai older adults. To the best of our knowledge, this is the first study using the 2-questions of the WHO-ICOPE and the first step 3-key questions

TABLE 2. Demographic data: Locomotor capacity.

Parameter	Normal locomotor capacity (n=152)	Locomotor capacity impairment (n=35)	Total (n=187)
Age (mean±SD)	69±6.4	76±6.7	70±7
Female, n (%)	105 (69.1)	20 (57.1)	125 (66.8)
Education, years (mean±SD)	13±4.6	10±4.8	12±4.7
Living alone, n (%)	24 (15.8)	5 (14.3)	29 (15.5)
Financial problem, n (%)	7 (4.6)	4 (11.4)	11 (5.9)
Hearing impairment, n (%)	4 (2.6)	4 (11.4)	8 (4.3)
Visual impairment, n (%)	54 (35.5)	18 (51.4)	72 (38.5)
Cognitive impairment, n(%)	11 (7.2)	6 (17.2)	17 (9.1)
Malignancy, n (%)	12 (8)	5 (14.7)	17 (9.2)
Stroke, n (%)	5 (3.3)	2 (5.7)	7 (3.7)
CAD, n (%)	6 (3.9)	3 (8.6)	9 (4.8)
DM, n (%)	32(21.2)	12 (34.3)	44 (23.7)
Osteoporosis, n (%)	9 (5.9)	3 (8.6)	12 (6.4)
Polypharmacy ≥ 5 drugs, n (%)	32 (21.1)	17 (48.6)	49 (26.2)
History of fall in past 1 yr, n (%)	13 (8.6)	11 (31.4)	24 (12.8)
Oral nutritional supplementation, n (%)	21 (13.8)	5 (14.3)	26 (13.9)
Gait aid use, n (%)	0	5 (14.3)	5 (2.6)
BMI, kg/m^2 (mean±SD)	23.1±4.4	24.2±4.7	23.3±4.4
Malnutrition, n (%)	23 (15.1)	7 (20)	30 (16)

TABLE 3. Validation of the malnutrition application compared with the MNA.

Validity/test	Malnutrition App. vs. MNA	Malnutrition App. include BMI<18.5 vs. MNA	Malnutrition App. include BMI<20 vs. MNA	Malnutrition App. include BMI<19.38 vs. MNA
Sensitivity	66.6%	90%	100%	100%
Specificity	96.1%	91%	81.5%	86.6%
PPV	76.9%	65.8%	50.8%	58.8%
NPV	93.7%	97.9%	100%	100%
LR+	16.8	10	5.3	7.1
LR-	0.35	0.11	0	0
Accuracy	96%	90.9%	84.5%	88.7%

Abbreviations: Malnutrition App. = Malnutrition application, MNA = Mini Nutritional Assessment, PPV = Positive predictive value, NPV = Negative predictive value, LR+ = Positive likelihood ratio, LR- = Negative likelihood ratio

TABLE 4. Validation of the limited mobility application compared with the SPPB.

Validity/test	Locomotor App. 3 questions vs. SPPB	Locomotor App. Q1 vs. SPPB	Locomotor App. Q2 vs. SPPB	Locomotor App. Q3 vs. SPPB
Sensitivity	94.2%	31.4%	74.2%	74.2%
Specificity	76.3%	90.1%	90.1%	84.2%
PPV	47.8%	42.3%	63.4%	52%
NPV	98.3%	85.1%	93.8%	93.40%
LR+	3.9	3.1	7.4	4.6
LR-	0.07	0.77	0.28	0.3
Accuracy	79.6%	83.1%	87.2%	82.4%

Abbreviations: Locomotor App. = Limited mobility application, SPPB = Short Physical Performance Battery Test, Q1 = Has fallen in the past year?, Q2 = Feels unsteady when standing or walking?, Q3 = Worries about falling?, PPV = Positive predictive values, NPV = Negative predictive values, LR+ = Positive likelihood ratios, LR- = Negative likelihood ratios

of the STEADI algorithm for screening for malnutrition and locomotor capacity impairment via application by self-screening, respectively. The questions are simple and short; thus, they are appropriate for older adults. The majority of the participants reported their high satisfaction with the application rated their excellent confidence in their ability to use the application by themselves.

In terms of baseline characteristics, there were more females than males, with a ratio of 2:1. This proportion may be higher than that of the general older adult population.[33] Approximately 16% of participants were diagnosed with at-risk malnutrition according to the MNA, which is lower than the pooled prevalence of at-risk malnutrition in Thai older adults as assessed by the MNA.[24] Similarly, when compared with the health survey of monks in the Bangkok Noi area of Bangkok, the monks exhibited a higher prevalence of elevated BMI and a lower prevalence of at-risk malnutrition compared to our participants.[34]

They were diagnosed with limited mobility by the SPPB at a rate of 18.7%, which is lower than that reported in a previous study;[26] this may be because, in this trial, the exclusion criterion excluded individuals with disabilities and severe dementia; those are the majority of malnutrition and mobility impairment patients. The group with locomotor dysfunction was older and had fewer years of education; more financial problems; cognitive impairment; hearing and visual impairment; a history of falls; polypharmacy; greater use of gait aids; and more cases of malnutrition. Thus, there are more comorbidities and fragilities.

The specificity of the malnutrition application tool, which involves two screening questions concerning weight loss and poor appetite, is excellent, but the sensitivity is fair. These results are similar to those of previous ICOPE face-to-face screening trials, but this trial was more sensitive and accurate. In the previous ICOPE face-to-face screening trial, researchers included BMI in screening for malnutrition. Thus, the sensitivity increased; this may be because BMI has high sensitivity by itself. We therefore added BMI to the application. The results show that the sensitivity increased, which is consistent with the previous face-to-face trial.[5,7-8,10,28-32]

In this study, the three questions in the application to screen for locomotor capacity impairment had high sensitivity, specificity, and good diagnostic value. This result resembles that of previous face-to-face studies; the sensitivity of the STEADI's three key questions ranged from 78.9 to 100%.[37-41] Therefore, this application may be used to screen for at-risk malnutrition and limited mobility by online self-screening in Thai older adults, except in an inpatient setting.

The strength of this study is its ability to screen older adults quickly. Compared with previous studies, screening by the MNA takes approximately 7–30 minutes[42], and the SPPB takes approximately 10–15 minutes.[11] However, this application takes almost 1–2 minutes to complete. Therefore, this application is a timesaving and age-friendly tool. Furthermore, the only additional equipment required is the individual's mobile phone or tablet. Moreover, individuals can use it independently, making it suitable for situations where face-to-face screening is challenging. This tool lowers the barriers to accessing the screening process. However, few studies have validated the screening performance of the first-step ICOPE tool and the first-step STEADI algorithm, especially in mobile or tablet applications.[27-31] This application is available for validation.

The limitations of this study are that the mean age of the participants was 69 years, which favors younger older adults, and the mean number of years of education favors higher education, which introduces selection bias but may be considered usual in a study that focuses on digital technology. Next, they were diagnosed with limited mobility by the SPPB fewer times than in the previous study;[25] this may be because, in this trial, the exclusion criterion excluded individuals with disabilities. Moreover, the use of the MNA as a standard diagnostic tool may be inconsistent because the gold standard for the diagnosis of malnutrition is the GLIM criteria. However, according to the MaNuEL study, the MNA can be used as a standard reference tool for evaluating the validity of nutritional screening instruments; these are considered ‘semigold’ reference standards and can substitute for the gold standard.[5-6,8,19] In this application, some words of the question can have an ambiguous meaning: “feel unsteady when standing or walking”. We evaluated the validity of the test, which provided good sensitivity, and afterward, the question could be used. The BMI is one part of the MNA that is used as a standard reference, which may lead to an increase in its validity. In the MNA, the BMI’s point is 2 out of a total score of 30, which is a minimal count and may not produce much change. However, the interpretation should be carefully considered. Next, this research did not test test-retest and interrater reliability because the participants lived in a distant area. As a result, the test’s reliability may decrease. Furthermore, the use of electronic devices among Thai older adults is limited. However, the current trend is to increase the use of electronic devices. In the future, if this application is validated for use by caregivers, it can be used by both older adults and caregivers.

For implementation, this application can be used by Thai older adults in noninpatient settings to screen for at-risk for malnutrition and limited mobility. Furthermore, this application can provide self-care information or suggestions for further evaluation when there are at-risk conditions that can be put in the application for immediate feedback. We should assess the test-retest and interrater reliability of the research to reduce the limitations in future research.

CONCLUSIONS

Combining BMI with the 2 questions of the WHO-ICOPE screening for malnutrition provides better sensitivity. However, BMI should be used with caution because it is a body composition metric that is included in the standard reference, the MNA. The first step, the 3-key question of the STEADI algorithm, which is applied to screen for limited mobility and fall risk, has high sensitivity and is appropriate for use as a screening tool in older adults. The majority of the participants reported their high satisfaction with the application rated their excellent confidence in their ability to use the application by themselves. Thus, this application is an age-friendly, time-saving tool that can be used when face-to-face screening is difficult.

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DECLARATION

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

P.T., W.M., S.I.- conceptualization, methodology, software, validation, resource. P.T., A.J., P.S.- investigation. P.T.- writing original draft. P.T., W.M.- visualization. W.M.-Project administration, funding acquisition. S.I.-supervision. P.T., W.M., S.I.- writing review and editing. All co-authors- final approval of the submitted manuscript.

Use of Artificial Intelligence

No artificial intelligence tools or technologies were used in the writing, analysis, or development of this research.

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