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Sensitivity and Specificity of Three Measures of Intrinsic Capacity in Older People Aged 80 and Over in Nursing Homes

Linlin Ma[1,2,*], Enjie Zheng[3,*], Yi Fang[1], Huixian Chen[1], Chuncong Zhou[4], Shuya Cai[1], Fen Luo[1], Wen Jiang[1], Jialu Wang[1,5], Xiangxiang Ning[6], Haixia Tu[1], Zhiqin Yin[1,7]

[1]School of Nursing, Wenzhou Medical University, Wenzhou, Zhejiang, People's Republic of China; [2]The Affiliated People's Hospital of Ningbo University, Ningbo, Zhejiang, People's Republic of China; [3]The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, People's Republic of China; [4]Nursing Department, Naval Hospital of Eastern Theater, Zhoushan, Zhejiang, People's Republic of China; [5]Department of Nursing, Ningbo No. 6 Hospital, Ningbo, Zhejiang, People's Republic of China; [6]College of Nursing, Ningbo College of Health Sciences, Ningbo, Zhejiang, People's Republic of China; [7]Wenzhou Health Promotion Research Center, Wenzhou, Zhejiang, People's Republic of China

*These authors contributed equally to this work

Correspondence: Zhiqin Yin; Haixia Tu, School of Nursing, Wenzhou Medical University, North Near the Intersection of Zhongxin North Road and Qiuzhen Road, Ouhai District, Wenzhou, Zhejiang, 325035, People's Republic of China, Tel +8613634269187; +8615088969190, Email yzq@wmu.edu.cn; tuhaixia2020@126.com

Purpose: Intrinsic capacity (IC), a crucial indicator for the United Nations Decade of Healthy Ageing 2021–2030, is defined by WHO as the foundation of functional ability, representing the composite of all physical and mental capacities of an individual. IC spans five function domains: Locomotor, psychological, cognitive, vitality, and sensory (including vision and hearing). Accurate IC assessment is vital for effective interventions, yet comparative analyses of these tools are scarce. Consequently, we evaluated the diagnostic accuracy of three IC assessment tools in individuals aged 80 and above—Integrated care for older people (ICOPE) Step 1, ICOPE Step 2, and the Lopez-Ortiz's IC scoring system.

Patients and Methods: This cross-sectional analysis included a total of 475 participants aged ≥80 years between July 2023 and January 2024 in 11 nursing homes in Ningbo, Zhejiang Province, China. To assess that included sociodemographic and health-related information alongside the three IC tools. Diagnostic efficacy was gauged using sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), accuracy, Youden index, and the area under the curve (AUC).

Results: The detection of IC decline exceeded 85% across all methods. Using ICOPE Step 2 as a benchmark, ICOPE Step 1 showed robust performance across four domains of locomotion, psychological, cognitive, and vitality, whereas the Lopez-Ortiz's IC scoring system was generally ineffective.

Conclusion: All three IC assessment methods have limitations. To save resources, ICOPE Step 1 can be considered for direct assessment in non-sensory domains. Conversely, the ICOPE Step 2 and Lopez-Ortiz's IC scoring systems exhibited overly stringent and lenient thresholds, respectively. At this stage, IC assessment tools cannot balance subjectivity and objectivity; thus, it is recommended that the appropriate tool be selected according to actual application scenarios. Continuous improvement of IC assessment tools remains a requirement for future studies.

Keywords: intrinsic capacity, aged 80 years and older, integrated care for older people, tool comparison, sensitivity and specificity, nursing homes

Introduction

The concept of intrinsic capacity (IC), a novel and pivotal person-centered measure encompassing five domains—locomotor, psychological, cognitive, vitality, and sensory (including vision and hearing)—was introduced by the World Health Organization (WHO) in 2015 by their "World Report on Aging and Health".[1,2] According to the "United Nations

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Decade of Healthy Ageing 2021–2030" plan, maintaining a high level of IC is essential for achieving healthy aging.[3] At its core, IC is a cornerstone of functional ability, with robust and stable IC crucial for longevity and overall health.[4,5]

Indeed, for medical professionals to implement effective interventions aimed at slowing, halting, or reversing the decline in IC, the initial step must involve an accurate assessment of IC loss. Consequently, how to precisely measure IC has emerged as a crucial issue in advancing the objective of healthy aging. To address this, the 2019 WHO "Integrated Care for Older People (ICOPE): Guidance for Person-centered Assessment and Pathways in Primary Care" handbook simultaneously introduced and recommended employing the ICOPE two-step method to assess IC in older adults in the community and primary healthcare facilities.[6] ICOPE Step 1 involves screening for IC through self-reports and a small number of objective tests, categorizing results based on the presence of decline or impairment. This approach is straightforward and cost-effective. ICOPE Step 2 offers a thorough assessment using validated objective scales and tests, yielding results that are more distinct and specific to the individual.

While the WHO recommends the ICOPE approach for progressively deepening the evaluation of IC in older adults—from screening in Step 1 to comprehensive assessment in Step 2, most existing studies have adopted only one of these methods to assess IC. This trend primarily stems from two factors: First, many IC studies rely on secondary analyses of retrospective datasets, constrained by data availability. Second, given the comprehensive and all-encompassing nature of IC indicators, despite their considerable research potential, the execution of empirical studies in real-world settings is inevitably limited by human and material resources. This limitation makes ICOPE Step 1 a more frequently utilized option due to its low threshold and affordability. Although a limited number of studies indicate that ICOPE Step 1 can serve as an effective and sensitive screening tool for IC in older adults within both community and clinical settings, a scoping review concerning the sensitivity and specificity of the ICOPE tool has raised questions about these findings.[7,8] In particular, when de Oliveira et al employed ICOPE Step 2 as the benchmark for assessment, the sensitivity across the five IC domains was found to range from 26.4% to 100%, and specificity varied from 22% to 96% in the few conducted studies, indicating considerable variation in performance.[9] This variability significantly challenges the reliability of the ICOPE Step 1. These observations underscore the imperative need for additional research to establish the reliability of the ICOPE tool across a broader spectrum of scenarios and elderly.

Acknowledging the global trend, the population segment aged 80 years and over (oldest-old) is expanding more rapidly than any other.[10] However, there appear to be some gaps in the literature regarding the validation of these measures in the oldest-old population, specifically those over 80 years of age. In particular, substantial evidence highlights the unique aspects of this age group across the five domains in evaluating IC, eg, cognitive impairment is prevalent in over 40% of these seniors, leading to declines in conceptual reasoning, processing speed, and memory as they age.[11,12] Research by Gonzalez-Bautista et al proposes adjusting the chair rise test cutoff from 14 to 16 seconds to refine the screening tool's psychometric attributes for individuals 80 years and older.[13] Additionally, it has been found that 93.2% of people in this demographic might underreport hearing loss.[14] Thus, exploring the specificities of IC assessment for seniors aged 80 and above is imperative. Nursing homes have been selected as the study setting due to their critical role in providing comprehensive care services for older adults, particularly in the context of China's aging population, which is increasingly characterized by illness, disability, solitary living, and the absence of familial support.[15] Currently, there is also a need for more research on IC in institutionalized settings.[16,17] As a critical indicator of functional capacity, IC holds great promise for use in institutionalized settings, and its reasonable use may significantly enhance the quality of care.

In the exploration of IC assessment methods, in addition to the ICOPE two-step method recommended by the WHO. We found that some scholars regarded the IC scoring system proposed by Lopez-Ortiz et al as another promising assessment method.[18] This scoring system, aligned with the ICOPE instrument's foundational concepts and objectives, aims to comprehensively assess the intrinsic capacity of older adults. Its primary advantage lies in offering a unified IC score that spans from 0 to 10, which is expected to address the problems of score aggregation in the current IC assessments, as well as significant heterogeneity and low comparability due to extensive operationalization.[19] Presently, empirical studies leveraging this scoring system still need to be explored. Consequently, our study adopted the Lopez-Ortiz's IC scoring system as a third assessment method, conducting a parallel assessment alongside ICOPE Steps 1 and 2 to gauge their efficacy across various diagnostic metrics, including sensitivity, specificity, accuracy, and so on.

Given the absence of a universally recognized gold standard for IC assessment, our study will evaluate the performance of the other two instruments by employing ICOPE Steps 1 and 2, respectively, as reference standards. In addition, we will include basic and instrumental activities of daily living (BADL and IADL) as criteria for stratification to determine the optimal threshold for the number of IC domains lost in older people across varying levels of disability. This approach will indirectly validate the effectiveness of the three IC assessment methods in the octogenarian population. Moreover, this research aims to enhance the body of evidence on the performance of the three IC assessment tools among individuals aged 80 and older, particularly within institutional settings.

This study is a follow-up to our previous research,[20] and the research questions for this study were: Which IC assessment tool is the most suitable for individuals aged 80 and above? Alternatively, what problems with each tool are not applicable? Additionally, what prospects and directions exist for enhancing these assessment tools?

Material and Methods

Design, Setting, and Participants

This cross-sectional study involved observing individuals aged ≥80 years who resided for ≥6 months in 11 Ningbo nursing homes from July 2023 to January 2024. Building upon our previous research protocol,[20] we excluded participants with: (1) severe communication disorders, including expressive language impairments and hearing deficits that prevented questionnaire completion; (2) significant visual limitations that would compromise safety during physical assessments; (3) severe cognitive decline (MMSE < 10) or advanced stages of dementia; (4) severe psychiatric disorders (eg, schizophrenia, severe anorexia nervosa, and obsessive-compulsive disorder); (5) acute medical conditions where institutional medical staff deemed participation unsafe; and (6) terminal illness or extreme frailty. These criteria were determined through comprehensive medical record review and joint assessment by both caregivers and research staff to ensure participants' capability to safely complete the comprehensive evaluation. Data collection was conducted in-person by trained personnel through standardized measurements and questionnaires. The study adhered to the Helsinki Declaration of Ethical Principles and received approval from the Ethics Committee of Wenzhou Medical University (No. 2023–005).

Sample Size

Assuming the prevalence of IC decline among older adults in China is 73.7%,[21] and following the sample size estimation guidelines for sensitivity and specificity tests proposed by Bujang and Adnan, a minimum sample of 245 subjects (including 196 subjects with IC decline) is sufficient to achieve a minimum power of 80%, based on a target significance level of 0.05.[22] This requirement was met.

Data Collection

Sociodemographic Information

We collected data on participants in age groups, gender, location, education, marital status, economic status, and duration of residence.

Health-Related Information

The BADL and IADL were assessed. The BADL was evaluated using the Barthel Index (BI). The overall scores varied from 0 to 100, with higher scores denoting greater independence. Specific score ranges indicate varying levels of function: 100 for total independence, 61–99 for mild disability, 41–60 for moderate disability, and 40 or below for severe disability.[23] The IADL was measured using the Functional Activities Questionnaire (FAQ). A score of <5 is considered normal and independent, while a score of ≥5 indicates that the individual cannot be independent in the family or society.[24]

ICOPE Step 1 (Method A) and ICOPE Step 2 (Method B)

ICOPE Steps 1 and 2 were proposed by the WHO in their "Integrated Care for Older People (ICOPE): Guidance for Person-centered Assessment and Pathways in Primary Care" guidelines in 2019.[6] ICOPE Step 1 is designed to initially screen older people for declines in IC within five key domains through simple and easily administered tests. Several screening questions are derived from standardized assessment tools: the Patient Health Questionnaire-9 (PHQ–9) for psychological assessment, Mini Nutritional Assessment (MNA) for vitality evaluation, Short Physical Performance Battery (SPPB) for motor function, and Mini-Mental State Examination (MMSE) for cognitive assessment. Building on Step 1's screening results, ICOPE Step 2 provides more comprehensive assessment using these complete scales, along with the WHO simple eye chart for vision and the Digits-in-noise test (hearWHO app) for hearing examination. However, neither step has standardized criteria for calculating total scores. The scoring details are presented in Table 1.

López-Ortiz's IC Scoring System (Method C)

López-Ortiz's IC scoring system was introduced in 2022 by López-Ortiz, this assessment methodology's distinctive features include: first, the recommended measurements are the same as in ICOPE Step 2 in the locomotion, cognitive, and vitality domains; second, it diverges from the previous methodologies by stratifying each domain through a scoring system ranging from 0 to 2 points, facilitating the computation of an overall IC score between 0 and 10.[19] The scoring details are presented in Table 1.

Data Analysis

This study utilized SPSS 23.0 (IBM Corp., Armonk, NY) and MedCalc 22.0 (MedCalc Software Ltd., Ostend, Belgium) for data analysis, starting with normality checks via the Kolmogorov–Smirnov test. Continuous variables were analyzed using the median (interquartile range, M (IQR)) for non-normal datasets, while categorical ones used counts and percentages (n (%)). Differences in IC domain losses across three methods were tested with chi-square tests, adjusting for error risk via Bonferroni correction.

Without a gold standard for IC assessment, first, we used Method B as the benchmark for the receiver operating characteristic curve (ROC) analysis to compare the detection effectiveness of Methods A and C, considering metrics like sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, Youden index, and the area under curve (AUC). Performance was classified based on sensitivity and specificity levels. The performance of the tool was deemed suitable if both sensitivity and specificity exceeded 80%; fair if either sensitivity or specificity was below 80% but above 50%; poor if either decreased below 50%.[25] PPV reflects the accuracy of the tool in identifying the disease, with a high PPV implying a low percentage of positive test results that are misdiagnosed as the disease. NPV represents the tool's ability to rule out disease, and a high NPV means a lower risk of missing disease in negative test results.[26] The Youden index (y = sensitivity + specificity - 1) is a metric for balancing sensitivity and specificity, with its value nearing 1 signifying optimal performance.[27] The AUC represents the total area beneath the ROC curve, with specific discriminative thresholds: >0.7 for moderate, >0.8 for good, and >0.9 for high discriminatory capacity.[28]

Second, the ROC's optimal cutoff was found through the highest Youden index, evaluating the discrepancy in performance between this and previous cutoffs for the Methods B and C scales, with Method A as the benchmark. The final step involved comparing the methods' ability to identify different disability levels in BADL and IADL, using AUC for assessment and DeLong tests for statistical significance at $P < 0.05$ with a 95% CI.

Results

Sample Characteristics

Four hundred and seventy-five samples that met the inclusion and exclusion criteria completed the survey. Among participants, 60.6% were female, with a median age of 87 years (IQR: 84–90). Most resided in urban areas (60.6%), were unmarried (68.4%), and 36.6% had not completed primary education. About half (49.1%) reported sufficient financial status. The modal institutional residence duration was 3–5 years (35.4%). In terms of self-care capability, 81.3% of participants displayed mild or greater disability in BADL, and 31.2% were assessed as unable to live independently based on IADL (Table S1).

Measurement of IC Using Three Assessment Methods in the Oldest-Old Group

ICOPE Step 1 screening showed "having almost no interest or pleasure in doing things" as the most common psychological domain issue (42.7%). Memory ability emerged as the most sensitive indicator in cognitive domain screening, affecting 40.0%

Table 1 Comparison of Three IC Assessment Tools

IC Domain	Method A: WHO ICOPE Step 1	Method B: WHO ICOPE Step 2	Method C: López-Ortiz's IC scoring system
	Tests and Standards	**Tests and Standards**	**Tests and Standards**
Psychological domain	**Over the past two weeks, have you been bothered by any of the following symptoms: 1. Feeling down, depressed, or hopeless? 2. Little interest or pleasure in doing things?** Participants who answered "yes" to either of these questions were considered to be depressed.	**PHQ–9 (Patient Health Questionnaire–9)** 0–2 points: no depression ≥ 3 points: depression	**CSDD (Cornell Scale for Depression in Dementia)** > 18 points: definitive major depressive episode (scored 0) 11–18 points: probably major depressive episode (scored 1) 1–10 points: normal psychological status (scored 2)
Locomotor domain	**Chair standing test: able to complete five chair rises without using arms in 14 seconds?** If unable to do so, considered to have limited mobility.	**SPPB (Short Physical Performance Battery) Δ** ≤ 9 points: limited mobility 10–12 points: normal mobility	**SPPB (Short Physical Performance Battery)Δ** 0–2 points: sarcopenia and cachexia (scored 0) 3–9 points: possible sarcopenia (scored 1) 10–12 points: robustness (scored 2)
Cognitive domain	Based on MMSE® (Mini–Mental State Examination), specific items not shown due to copyright restrictions		
Vitality domain	**1. Weight loss: Have you unintentionally lost more than 3 kg over the last three months? 2. Appetite loss: Have you experienced a loss of appetite?** Participants who answered "yes" to any of the questions were considered to be malnourished.	**MNA (Mini–Nutritional Assessment)Δ** < 17 points: malnourished 17–23.5 points: at risk of malnutrition 24–30 points: normal nutritional status	**MNA (Mini–Nutritional Assessment)Δ** < 17 points: malnourished (scored 0) 17–23.5 points: at risk of malnutrition (scored 1) 24–30 points: normal nutritional status (scored 2)
Sensory domain (Visual)	**Do you have any problems with your eyes: difficulties in seeing far, reading, eye diseases, or currently receiving medical treatment (eg diabetes, high blood pressure)?** Participants who answered "yes" had impaired vision.	**The WHO simple eye chart**. **1. Distance vision test**: ≥ 6/18: pass the distance vision screening test [a] < 6/18: fail the distance vision screening test [b] **2. Near vision test**: Can recognize the directions of at least three out of four largest Es with natural vision or with glasses: pass the near vision screening test. Still cannot recognize it with glasses: fail the near vision screening test	**Self-reported** Total or severe loss/alteration of hearing (scored 0) Moderate loss/alteration of hearing (scored 0.5) Normal or mild loss/alteration of hearing (scored 1)

(*Continued*)

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Table 1 (Continued).

IC Domain	Method A: WHO ICOPE Step 1	Method B: WHO ICOPE Step 2	Method C: López-Ortiz's IC scoring system
	Tests and Standards	**Tests and Standards**	**Tests and Standards**
Sensory domain (Hearing)	**Do you have any hearing problems?** Participants who answered "yes" or had a relevant medical certificate representing hearing impairment.	**Digits-in-noise test (hearWHO app)** ≥ 50 points: pass hearing screening test (including 50–75 points needing regular checkups and >75 points indicating good hearing) <50 points: fail hearing screening test (indicates some degree of hearing loss)	**Self-reported** Total or severe loss/alteration of vision (scored 0) Moderate loss/alteration of vision (scored 0.5) Normal or mild loss/alteration of vision (scored 1)
IC scoring	/	/	0–4.5 points: significant loss of capacity 5–8.5 points: declining capacity 9–10 points: high and stable capacity

Notes: Δ indicates that the specific measurements of the two test methods in this IC domain are the same. [a] ≥ 6/18 including 6/18 and > 6/18; 6/18 represents the ability to see in the direction of at least 3 of the 4 small Es tested with 4 small Es at 3 meters; > 6/18 represents better visual acuity than 6/18; [b] < 6/18 includes 6/60, 3/60, and < 3/60; 6/60 represents the ability to see at least 3 out of 4 Big Es when tested with Big Es at 3 meters; 3/60 represents the ability to see at least 3 or worse out of 4 big Es when tested with big Es at 1.5 meters; <3/60 represents the ability to see less than 3/60.
Abbreviations: WHO, World Health Organization; ICOPE, integrated care for older people; IC, intrinsic capacity.

of participants. Loss of appetite (40.8%) was more common than weight loss (19.6%) in the vitality domain. ICOPE Step 2 assessments revealed over half of the oldest-old passed tests in psychological (55.6%), cognitive (56.4%), and vitality (50.9%) domains. In vision domain, only 33.3% of the oldest-old met the normal standard for distance vision (≥6/18), significantly lower than the proportion with normal near vision (75.8%). The locomotor domain showed the highest proportion of impairment among all domains in both ICOPE Step 1 (82.7%) and Step 2 (83.8%). The median total score for IC among participants using the López-Ortiz IC scoring system was 8.0 (IQR: 4.5, 9.0). The assessment found that 43.4% of participants experienced IC decline, 31.6% had high and stable IC, and 25.1% showed significant IC loss (Tables S2 and S3).

IC Decline in Adults Aged 80 and Above Using Three Assessment Methods

Table 2 illustrated that IC decline rates above 85% were detected by all three methods. Method B identified the highest proportion, reaching 91.8%. After the Bonferroni correction, a significant difference was noted in the IC decline detection rates between Methods B and C (P = 0.037). In the psychological domain, Methods A and B both significantly differed from Method C in depression detection (all $P < 0.001$), with Method C identifying the lowest proportion of depression among older people at 30.5%. In the vision, hearing, and overall sensory function domains, Method B's identification rates were notably higher than those of the other two methods, at 67.4%, 77.5%, and 81.7%, respectively, with significant differences in pairwise comparisons across these domains (all $P < 0.01$). However, in the locomotor, cognitive, and vitality domains, no significant difference was observed between Methods A and B (Method C's measurements in these three domains were consistent with Method B).

Evaluation of the Diagnostic Performance of Methods a and C Using Method B as the Benchmark

As shown in Table 3, Methods A and C show high AUC values (0.942 and 0.972) for IC decline detection. However, their performance in NPV, at 67.9% for A and 61.9% for C, indicates a potential higher miss rate in identifying IC decline. In the psychological domain, despite Method C achieving 100% in both specificity and PPV, ensuring absolute reliability of positive outcomes, its lower sensitivity (68.7%) and NPV (61.9%) suggest a higher likelihood of missed diagnoses. In contrast, Method A significantly surpasses C in most diagnostic metrics within the psychological domain, particularly in Youden's index (0.858) and the AUC (0.929), reinforcing its credibility in psychological diagnosis. Furthermore, Method A also excels in other domains: it achieves near-perfect performance in the locomotor domain (AUC = 0.970), and maintains

Table 2 IC Losses Were Obtained Using the Three Methods of Assessment

Items	Method A	Method B	Method C	Unadjusted *P*-Values[a]	Adjusted *P*-Values[b]		
					A vs B	A vs C	B vs C
IC decline detection rate (at least ≥ 1 domain)	422 (88.8%)	436 (91.8%)	412 (86.7%)	**0.043**	0.433	0.891	**0.037**
IC domain							
Psychological	235 (49.5%)	211 (44.4%)	145 (30.5%)	**< 0.001**	0.329	**< 0.001**	**< 0.001**
Locomotor	393 (82.7%)	398 (83.8%)	Same B	0.664	/	/	/
Cognitive	194 (40.8%)	207 (43.6%)	Same B	0.393	/	/	/
Vitality	208 (43.8%)	233 (49.1%)	Same B	0.104	/	/	/
Sensory (Vision)	253 (53.3%)	320 (67.4%)	190 (40.0%)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
Sensory (Hearing)	226 (47.6%)	368 (77.5%)	179 (37.7%)	**< 0.001**	**< 0.001**	**0.004**	**< 0.001**
Sensory (Vision + Hearing)	296 (62.3%)	388 (81.7%)	235 (49.5%)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Note: [a]Chi-square test; [b]Bonferroni correction based on the chi-square test; Bold *P*-values indicate statistical significance ($P < 0.05$). Method A: ICOPE Step 1; Method B: ICOPE Step 2; Method C: López-Ortiz's IC scoring system.
Abbreviation: IC, intrinsic capacity.

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Table 3 Evaluation of ICOPE Step 1 and López-Ortiz's IC Scoring System Using ICOPE Step 2 as the Benchmark

Method A (ICOPE Step 1) vs Method B (ICOPE Step 2)										
IC Domain	**A**	**B**		**Sensitivity (%)**	**Specificity (%)**	**PPV (%)**	**NPV (%)**	**Youden Index**	**AUC**	**Accuracy (%)**
		+	**–**							
IC decline detection rate (at least ≥ 1 domain)	+	419	3	96.1 (93.8–97.7)	92.3 (79.1–98.4)	99.3 (97.9–99.8)	67.9 (56.8–77.3)	0.884	0.942 (0.917–0.961)***	95.8 (93.6–97.4)
	–	17	36							
Psychological	+	205	30	97.2 (93.9–98.9)	88.6 (84.2–92.2)	87.2 (83.0–90.5)	97.5 (94.7–98.9)	0.858	0.929 (0.902–0.950)***	92.4 (89.7–94.6)
	–	6	234							
Locomotor	+	390	3	98.0 (96.1–99.1)	96.1 (89.0–99.2)	99.2 (97.7–99.7)	90.2 (82.3–94.8)	0.941	0.970 (0.951–0.984)***	97.7 (95.9–98.8)
	–	8	74							
Cognitive	+	175	32	84.5 (78.9–89.2)	92.9 (89.2–95.7)	90.2 (85.6–93.4)	88.6 (85.0–91.5)	0.775	0.887 (0.855–0.914)***	89.3 (86.1–91.9)
	–	19	249							
Vitality	+	199	9	85.4 (80.2–89.7)	96.3 (93.1–98.3)	95.7 (92.1–97.7)	87.3 (83.4–90.3)	0.817	0.908 (0.879–0.933)***	90.9 (88.0–93.4)
	–	34	233							
Sensory (Vision)	+	240	13	75.0 (69.9–79.7)	91.6 (86.1–95.5)	94.9 (91.6–96.9)	64.0 (59.3–68.3)	0.666	0.833 (0.796–0.865)***	80.4 (76.6–83.9)
	–	80	142							
Sensory (Hearing)	+	224	2	60.9 (55.7–65.9)	98.1 (93.4–99.8)	99.1 (96.6–99.8)	42.2 (39.0–45.4)	0.590	0.795 (0.756–0.830)***	69.3 (64.9–73.4)
	–	144	105							
Sensory (Vision + Hearing)	+	290	6	74.7 (70.1–79.0)	93.1 (85.6–97.4)	98.0 (95.7–99.1)	45.3 (40.8–49.7)	0.678	0.839 (0.803–0.871)***	78.1 (74.1–81.7)
	–	98	81							
Method C (López-Ortiz's IC scoring system) vs Method B (ICOPE Step 2)										
IC domain	**C**	**B**		**Sensitivity (%)**	**Specificity (%)**	**PPV (%)**	**NPV (%)**	**Youden index**	**AUC**	**Accuracy (%)**
		+	**-**							
IC decline detection rate (at least ≥ 1 domain)	+	412	0	94.5 (91.9–96.4)	100.0 (91.0–100.0)	100.0 (99.1–100.0)	61.9 (52.4–70.6)	0.945	0.972 (0.953–0.985)***	94.9 (92.6–96.7)
	-	24	39							

Psychological	+	145	0	68.7 (62.0–74.9)	100.0 (98.6–100.0)	100.0 (97.5–100.0)	80.0 (76.6–83.0)	0.687	0.844 (0.808–0.875)***	86.1 (82.7–89.1)
	-	66	264							
Sensory (Vision)	+	188	2	58.8 (53.1–64.2)	98.7 (95.4–99.8)	98.9 (95.9–99.7)	53.7 (50.4–56.9)	0.575	0.787 (0.748–0.823)***	71.8 (67.5–75.8)
	-	132	153							
Sensory (Hearing)	+	179	0	48.6 (43.4–53.9)	100.0 (96.6–100.0)	100.0 (98.0–100.0)	36.1 (33.9–38.5)	0.486	0.743 (0.701–0.782)***	60.2 (55.7–64.6)
	-	189	107							
Sensory (Vision + Hearing)	+	234	1	60.3 (55.2–65.2)	98.9 (93.8–100.0)	99.6 (97.1–99.9)	35.8 (33.0–38.7)	0.592	0.796 (0.757–0.831)***	67.4 (62.9–71.6)
	-	154	86							

Note: 95% CI in parentheses; *** represents *P* < 0.001. A represents Method A: ICOPE Step 1; B represents Method B: ICOPE Step 2; C represents Method C: López-Ortiz's IC scoring system.
Abbreviations: ICOPE, integrated care for older people; IC, intrinsic capacity; NPV, negative predictive value; PPV, positive predictive value; AUC, the area under the curve.

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strong performance in cognition (AUC = 0.887) and vitality (AUC = 0.908) domains, despite slightly lower AUCs. Method C shows weaker performance in sensory areas, with AUCs below 0.8 for hearing (0.743), vision (0.787), and overall sensory (0.796). Meanwhile, despite Method A's less-than-optimal sensitivity and negative predictive values in the sensory areas hinting at some risk of missed diagnoses, its overall performance is marginally higher than Method C, except for in hearing, where the AUC does not reach 0.8, its vision and overall sensory performances achieve AUC values above 0.8.

Evaluating the Diagnostic Performance of Methods B and C Using Method a as the Benchmark

Table 4 showed that for PHQ–9 and MMSE, the optimal and original cutoff coincided, achieving the highest sensitivity and specificity with the Youden index between 0.788 and 0.847. SPPB and MNA optimal cutoffs were close to the previously recommended value, with the Youden index over 0.8, maintaining high diagnostic performance across thresholds. However, significant gaps between two cutoff points were observed for CSDD, hearWHO, and the WHO simple vision chart. CSDD showed a notable improvement in the Youden index to 0.810 at an optimal cutoff value of 5 points, indicating stable sensitivity and specificity. In contrast, the hearWHO and WHO simple eye charts showed no significant performance improvement at optimal cutoffs (Youden index: 0.506–0.635).

Comparison of ROC Curves and Optimal Cutoff Values in the Three Assessment Methods at Different BADL and IADL Levels

Figure 1 shows that all three IC assessment methods exhibit excellent diagnostic performance at different BADL and IADL levels (AUC = 0.899–0.974). In terms of BADL, the common feature of Methods A and B is that they are best suited to diagnose the no-disability state when the IC loss domain is ≤1 item, best suited to diagnose mild-to-moderate disablement when the loss is ≤4 items, and best reflect the severe disablement state when the loss is >4 items. The

Table 4 Evaluation of ICOPE Step 2 and López-Ortiz's IC Scoring System Using ICOPE Step 1 as the Benchmark

Test	Cutoff Value	Sensitivity (%)	Specificity (%)	Youden Index
PHQ–9	≥ 3[a, b]	87.2 (82.3–91.2)	97.5 (94.6–99.1)	0.847
CSDD	≥ 5[a]	86.4 (81.3–90.5)	94.6 (90.9–97.1)	0.810
	≥ 11[b]	57.9 (51.3–64.3)	100.0 (98.5–100.0)	0.579
SPPB	≤ 8[a]	88.9 (85.5–91.7)	98.1 (89.9–100.0)	0.870
	≤ 9[b]	93.1 (90.3–95.3)	90.6 (79.3–96.9)	0.837
MMSE	≤ 26[a, b]	90.2 (85.1–94.0)	88.6 (84.3–92.1)	0.788
MNA	≤ 23[a]	94.7 (90.7–97.3)	88.8 (84.3–92.3)	0.835
	≤ 23.5[b]	95.7 (91.9–98.0)	87.3 (82.7–91.0)	0.830
HearWHO	≤ 20[a]	76.1 (70.0–81.5)	84.3 (79.2–88.6)	0.604
	≤ 50[b]	100.0 (98.4–100.0)	28.1 (22.6–34.1)	0.281
WHO simple vision chart (distance)	≤ 3/60[a]	71.2 (65.1–76.6)	92.3 (88.0–95.5)	0.635
	≤ 6/60[b]	94.1 (90.4–96.6)	64.0 (57.3–70.3)	0.581
WHO simple vision chart (near)	Recognized directly without tools[a]	92.5 (88.5–95.4)	58.1 (51.3–64.7)	0.506
	Remained unrecognizable with tools[b]	43.9 (37.7–50.2)	98.2 (95.5–99.5)	0.421

Notes: 95% CI in parentheses. [a]The optimal cutoff value; [b]The previously recommended value.
Abbreviations: ICOPE, integrated care for older people; PHQ–9, Patient Health Questionnaire–9; CSDD, Cornell Scale for Depression in Dementia; SPPB, Short Physical Performance Battery; MMSE, Mini–Mental State Examination; MNA, Mini–Nutritional Assessment; WHO, World Health Organization; AUC, the area under the curve.

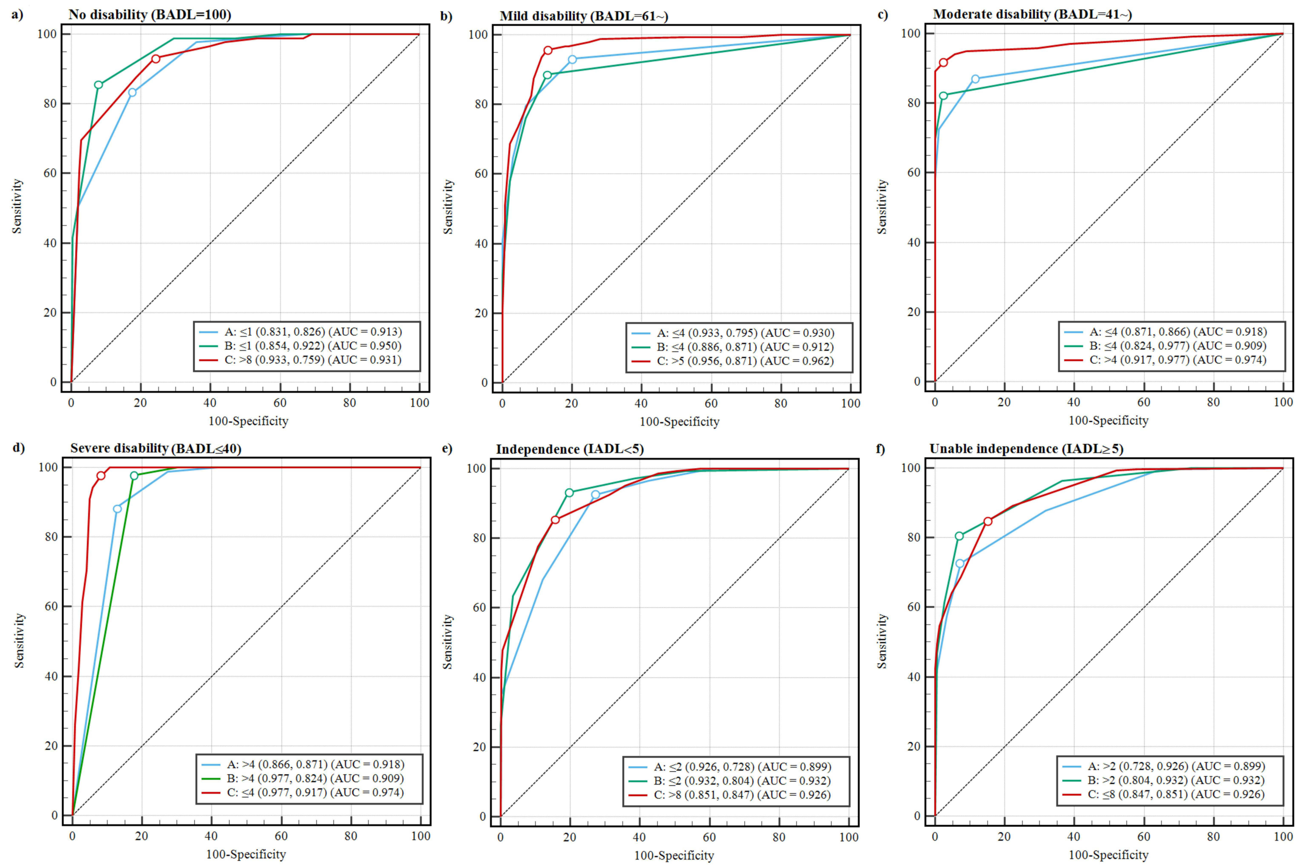

Figure 1 Comparison of ROC curves with optimal cutoff values for the three IC measures to detect different levels of BADL and IADL in participants. (**a**) shows no disability (BADL=100), (**b**) shows mild disability (BADL=61~), (**c**) shows moderate disability (BADL=41~), (**d**) shows severe disability (BADL<40), (**e**) shows Independence (IADL<5), and (**f**) shows unable independence (IADL≥5).

Notes: The optimal cutoff (sensitivity, specificity) and the area under the curve (AUC) indicated by the marker on each curve are reported in parentheses. A represents Method A: ICOPE Step 1; B represents Method B: ICOPE Step 2; C represents Method C: López-Ortiz's IC scoring system.

Abbreviations: BADL, basic activities of daily living; IADL, instrumental activities of daily living; AUC, the area under the curve.

optimal cutoffs for Method C in the no-disablement, mild-disablement, and moderate-to-severe-disablement states are >8 points, >5 points, >4 points, and ≤4 points, respectively. From the IADL analysis, Methods A and B were best suited to diagnose the state of instrumental self-care when there were ≤2 items in the IC loss domain and performed best for diagnosing instrumental incapacity for self-care when the optimal cutoff value was >2. The results of Method C showed that >8 and ≤8 points represented the optimal cutoff values for instrumental independence and dependence, respectively.

Discussion

Our research indicates that using any of the three IC assessment methods on individuals aged 80 and above in nursing homes results in a detection rate of IC decline of over 85%, clearly demonstrating that the IC status in this population is not ideal.

In conclusion, we found that ICOPE Step 1 can be a reliable alternative to ICOPE Step 2 in the domains of psychology, cognition, vitality, and locomotor domains. This was concluded due to the higher Youden index, higher accuracy, and almost consistent critical values. This likely results from the assessment items in these four domains in ICOPE Step 1 directly deriving from the ICOPE Step 2 scales, allowing for already good performance at the screening level in these domains.

Diverging from previous research, this study may currently be the one that reports the best overall performance of ICOPE Step 1 in detecting IC decline. This is mainly reflected in the substantially improved specificity performance, surpassing Lu et al's 62.3% and Leung et al's 57.6%.[29,30] Despite questions on its sensitivity in the sensory domain, ICOPE Step 1 still shows potential as a tool for monitoring IC decline among individuals aged 80 and above. However, it is crucial to approach this conclusion cautiously, as the prevalence of IC decline in octogenarians might inadvertently enhance the tool's overall performance.

However, we have concerns about ICOPE Step 1's performance in the sensory domain. Despite high specificity (91.6%–98.1%), its sensitivity is low (60.9%–75.0%). When used as the gold standard, significant discrepancies emerge in cutoff values for hearWHO and the WHO simple vision chart. This suggests a substantial risk of underdiagnosis in vision, hearing, or overall sensory evaluations, potentially rendering sensory domain screening unreliable. We suspect this primarily stems from three key factors in sensory self-assessment. First, older adults tend to overestimate their sensory capabilities, particularly hearing ability, as documented in previous research.[14] Second, the nursing home context may influence self-reporting, as residents might consider their sensory function "sufficient" for their current environment's demands,[31] unlike those living in community or hospital settings who face different sensory challenges. Third, the lower reporting of sensory impairments might also reflect limitations in the assessment approach itself – current screening tools may not adequately accommodate the complex communication needs of older adults, potentially making it difficult for them to effectively report their sensory difficulties. For instance, hearing impairment might affect their ability to understand assessment instructions, while visual limitations could impact their interaction with screening materials.[32,33] These compounded factors particularly affect ICOPE Step 1's performance in sensory domain assessment. The tool's reliance on simplified screening questions, while enabling rapid assessment, often fails to detect subtle but significant sensory deficits that impact daily function.

Compared to the previous studies comparing ICOPE Steps 1 and 2, our results relate closely to Luque et al, suggesting a good consistency between ICOPE Step 1 and Step 2 in domains other than the sensory domain. Unlike their study, they did not find significant between-group differences in the visual domain, and their study population was ≥70 years old.[7] In contrast, our study found significant differences in both individual and combined sensory domains (all $P < 0.001$). In addition, the issue of lower sensitivity in vision and hearing assessments in both ICOPE steps was also reported by Lu et al in a study involving participants aged ≥75 years.[29] This prompts us to consider whether overestimating sensory capabilities is more common among older age groups at more advanced ages. Because, Leung et al did not report similar findings in participants aged ≥60 years.[30]

However, it is important to note that our findings are based solely on octogenarians in nursing homes, and current research evaluating ICOPE Steps 1 and 2's sensitivity and specificity across different populations remains limited. The notably improved accuracy achieved through ICOPE Step 2's objective assessment methods suggests that the two-step approach works as intended – Step 1 serving as an initial filter to identify potential issues, particularly valuable in resource-limited settings, while Step 2 provides the necessary detailed assessment. Despite some limitations in sensory assessment, ICOPE Step 1 remains valuable as an initial rapid screening tool, with the key lying in understanding its limitations and using it appropriately. This staged approach allows for efficient resource allocation while ensuring comprehensive evaluation when needed. Further validation studies across diverse populations and settings are needed to better understand the tool's performance characteristics and optimize its implementation in different contexts.

A literature review revealed that recent research by Cacciatore et al explored IC assessment in adults aged 80 and above using MDS-HC data.[34] Their approach of extracting and combining existing MDS-HC items related to IC domains offers advantages in utilizing established comprehensive assessment data and potentially reducing additional assessment burden. However, this differs from ICOPE Steps 1 and 2, which provide a structured framework specifically designed and validated for IC assessment across multiple studies. While using existing assessment data may be efficient, such post-hoc adaptation presents limitations in standardization and comparability. Similar challenges exist in many IC studies derived from large cohort studies. Currently, we lack understanding of potential biases, beyond comparability issues, that may arise when studies follow WHO's five IC domains but deviate from recommended assessment methods.

At this stage, there remains no universally accepted measurement tool for intrinsic capacity, and validation studies of assessment tools are still limited. Among various proposed approaches, the Lopez-Ortiz's IC scoring system has been frequently cited as a potential solution to the limitation of standardized scoring in ICOPE screening tools.[35] As the first comprehensive empirical examination of this system, our findings indicate that several critical issues need to be addressed before recommending its widespread adoption. The first issue concerns its sensitivity and specificity balance.

While achieving 100% specificity in some domains, its low sensitivity might miss actual IC loss. This artificially high specificity appears to result from overly lenient thresholds for normalcy, as evidenced by our finding that the optimal cutoff point for the CSDD was 5, substantially lower than the original threshold of 11. This suggests a need for threshold recalibration to better balance sensitivity and specificity.

The second major concern relates to its scoring criteria, particularly in sensory domains. The system's criteria for a full score (1 point) encompass both "normal" and "mild impairment" conditions, creating ambiguity in assessment. In our study, 13.3% and 9.9% of participants received full scores despite reporting mild vision and hearing impairments, respectively. While such mild sensory impairments might not significantly impact our study population of octogenarians, they could be early indicators of decline in younger elderly populations. This suggests the need for a more graduated scoring scale that better differentiates between normal function and mild impairment. The third major methodological limitation pertains to cognitive assessment. We excluded participants with severe cognitive impairments (MMSE < 10) due to their inability to complete general information and other domain assessments. Consequently, in practical implementation, the cognitive domain of the Lopez-Ortiz's IC scoring system could not be rated as 0, with scores limited to a minimum of 1. This constraint potentially introduces systematic bias in the total scores, suggesting the need for alternative evaluation methods, such as proxy assessments, to accommodate individuals with severe cognitive impairment.

Finally, we note that ICOPE Step 2 might also have an issue setting overly high normal thresholds for individuals aged 80 and above. A previous systematic review reported a comprehensive detection rate of IC decline among older adults in China at 73.7%.[21] Considering the higher age bracket of our study population, we can be reasonably confident in the high credibility of our data. However, when observing other findings, normal BADL and IADL were best diagnosed at a loss of one and two IC domains, respectively, whereas the delineation point for mild-to-moderate disability in BADL had expanded to a loss of four IC domains. This leads us to infer the possibility that in the older age group of 80 years and older, the loss of some objective IC ability does not significantly affect the functional performance of that ability in subjective activities of daily living and that they may have adapted to this gradual decrease in IC with age.

However, as emphasized by Hoogendijk et al, it is currently unclear whether elderly individuals wish to undergo clinical evaluations based on their IC.[36] Considering this perspective, incorporating the impact on daily life as a criterion for IC assessment seems reasonable – when older individuals report the need for assessment and improvement, it may indicate that dysfunction has reached a level that truly affects their daily functioning. Such an approach could potentially increase participation and improve intervention cost-effectiveness. However, relying solely on older adults' self-reported need for assessment presents significant limitations. First, older individuals may not accurately recognize or report how IC decline affects their daily functioning, particularly given the tendency to normalize gradual functional changes.[37] Second, even when impacts are reported, various barriers (such as healthcare access, resource limitations, or communication challenges) might prevent appropriate follow-up.[38] Therefore, future research should focus on developing more comprehensive approaches that combine both subjective needs and objective assessments. This could involve regular screening protocols, systematic follow-up mechanisms, and consideration of both perceived and objectively measured functional impacts. The choice between emphasizing objective assessments or subjective self-assessments in IC assessment tools should be aligned with these multiple factors. A new IC assessment tool that balances subjective and objective evaluations should be explored in the future. Additionally, existing assessment tools should be improved to establish appropriate thresholds for different populations while ensuring systematic follow-up procedures.

Limitations

Our study had several limitations to consider. First, our study focused on adults aged 80 and above residing in nursing homes in a specific region of China, which inevitably affects the generalizability of our conclusions. Second, the cross-sectional design restricts our ability to observe changes in the effectiveness of IC assessment methods over time. This limitation is particularly significant given the absence of a universally accepted gold standard for IC assessment, which affects our ability to definitively determine method superiority. Future research should focus on developing such a gold standard through long-term studies that examine how different IC measurements relate to health outcomes while engaging multidisciplinary teams to validate assessment tools against comprehensive geriatric evaluations. Third, despite the varied methods for measuring IC, our study aimed to follow the WHO-recommended ICOPE two-step process and Lopez-Ortiz's IC scoring system to ensure data comparability. However, we must admit that our assessment in the hearing domain did not strictly follow the ICOPE two-step process. This was mainly due to the diagnostic hearing tests recommended by the WHO in ICOPE Step 2, such as pure-tone audiometry, speech audiometry, and tympanometry, which are inaccessible to us, require specialized training, and are deemed impractical at the primary care level. After consulting with experts and considering that self-reporting is currently the most common assessment method in the hearing domain, we modified ICOPE Step 1 to self-reporting (originally whisper test/screening audiometry/digital noise test through automated applications) and used the hearWHO app for objective assessment in ICOPE Step 2 (originally diagnostic hearing tests). Although this differs from the WHO's recommended methods, adopting a combined subjective and objective assessment approach adds credibility to our study. Indeed, we find the current guidelines on hearing assessment to have low practicability and hope future research will continue to refine this area to increase its feasibility in primary care.

Conclusion

This study is the first empirical research to compare the performance of three widely recognized IC assessment tools. Regardless of the IC tool used, the rate of IC loss among individuals aged 80 and above in nursing homes is high. To save resources, ICOPE Step 1 can be considered for direct assessment in non-sensory domains. Both ICOPE Step 2 and the Lopez-Ortiz's IC scoring system may have issues setting too high or too low thresholds for this population. Moreover, several critical issues with the Lopez-Ortiz's IC scoring system need clarification. Additionally, continued empirical research evidence and improvement proposals are necessary for IC assessment tools.

Data Sharing Statement

The data set used in this research is available from the corresponding author upon a reasonable request.

Ethics Approval and Informed Consent

This study was approved by the Ethics Committee of Wenzhou Medical University (No. 2023-005). All participants provided written informed consent, and the study was performed following the principles of the Declaration of Helsinki. All data collected from subjects remained anonymous and confidential to protect their privacy.

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An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

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Disclosure

All authors have no conflicts of interest with this study.

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