BMC Geriatrics

RESEARCH

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Correlates of mild behavioural impairment in older adults: a scoping review

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Abstract

Background Mild behavioural impairment in older adults has emerged as a potential precursor to cognitive decline and the onset of dementia. While the characteristics of mild behavioural impairment are documented, less is known about its correlates. A clearer understanding of these correlates could improve early detection and intervention strategies.

Objective This study synthesised the evidence demonstrating the correlates of mild behavioural impairment in older adults. The specific objectives included (1) identifying trends in publications and research designs related to mild behavioural impairment, and (2) determining the correlates of mild behavioural impairment.

Methods A scoping review was conducted using the Joanna Briggs Institute methodology and adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews checklist to report results.
We sourced from research articles in PubMed (MEDLINE), CINAHL, PsycINFO, EMBASE, the Cochrane Library, SCOPUS, and Web of Science across the period January 2003 to May 2024. The search terms were structured around participant–concept–context parameters: older adults as participants, mild behavioural impairment as the concept, and an unrestricted context. The data were extracted by three independent reviewers using an a priori extraction tool.

Results A total of 41 research articles were selected. A consistent increase in the number of publications since 2009 was identified, with a notable surge in 2022 and 2023. Most studies employed cross-sectional designs, demonstrating correlates predominantly classified into three categories: (1) neurocognitive factors such as beta-amyloid and tau protein; (2) physical factors, including frailty; and (3) psychosocial factors, particularly those focusing on depressive symptoms.

Conclusions This review highlights a growing body of evidence linking neurocognitive, physical, and psychosocial factors to mild behavioural impairment in older adults. Among these, psychosocial correlates—particularly depressive symptoms—were most consistently reported, underscoring their potential relevance for intervention. Given their modifiable nature, these factors represent promising targets for tailored psychosocial or mental health strategies. Future research should prioritise longitudinal and interventional designs to clarify temporal relationships and assess the impact of these interventions on mitigating mild behavioural impairment and subsequent functional decline.

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Keywords Aged, Behavioural symptoms, Mild behavioural impairment, Neuropsychiatric symptoms

Background

The increasing prevalence of dementia, driven by an aging population worldwide, represents a critical public health challenge. By 2050, an estimated 152 million people will be affected globally, with associated costs exceeding US$1 trillion annually [1]. Dementia typically develops gradually, and is often preceded by subtle cognitive and behavioural changes that emerge during the prodromal stage [2]. Although there is no definitive treatment for dementia, early identification and interventions targeting modifiable risk factors may help delay progression and reduce the burden of decline in cognitive and behavioural functioning [3, 4].

Much of the early dementia research focused on cognitive indicators such as subjective cognitive decline—defined as self-perceived cognitive worsening in the absence of objective impairment—and mild cognitive impairment, which involves measurable cognitive deficits that do not yet interfere significantly with daily functioning [3, 5, 6]. These stages primarily capture cognitive changes and behavioural symptoms that can also emerge early in the disease trajectory. In line with global trends, most cognitive and behavioural studies have focused on older adults, typically aged 60 years and above. However, the operational definition of "older adults" varies internationally, and studies often adopt context-specific age thresholds based on national or institutional criteria [7]. These individuals are key targets for dementia prevention initiatives due to their risk of progression to cognitive and behavioural impairment and eventual dementia [8–10].

In this context, mild behavioural impairment has emerged as a complementary framework for understanding later-life behavioural and personality changes that may precede or co-occur with cognitive decline [5, 11, 12]. Introduced by Taragano and colleagues in 2003, mild behavioural impairment is defined as a syndrome of sustained neurobehavioural symptoms in older adults that persist for at least six months and are not better accounted for by existing psychiatric diagnoses [13]. These symptoms typically fall into five domains: decreased motivation (such as apathy), affective dysregulation (including anxiety or depression), impulse dyscontrol (such as agitation or irritability), social inappropriateness (including disinhibition), and abnormal perception or thought content (such as delusions or hallucinations) [11]. Given that mild behavioural impairment often appears with cognitive changes, its value has been considered to be identifying individuals at elevated dementia risk before substantial cognitive or functional deterioration occurs [14].

Since its formal conceptualisation in 2003 [15], research on mild behavioural impairment has expanded to include its clinical assessment, sociodemographic and biological associations, and relevance in different disease contexts. The development of standardised tools—such as the Mild Behavioural Impairment Checklist—has enabled more consistent evaluation of mild behavioural impairment in both clinical and community settings [11, 16–18]. Despite growing interest, studies on mild behavioural impairment remain scattered across populations, settings, and study designs [15, 19, 20].

A comprehensive synthesis of the evidence on factors associated with mild behavioural impairment is, therefore, essential. Such a synthesis can help clarify its role in dementia risk stratification, inform clinical monitoring, and guide the development of preventive interventions. To address this need, the present scoping review aimed to identify and categorise the correlates of mild behavioural impairment among older adults across the cognitive spectrum, from normal cognitive function to mild cognitive impairment. We use the term 'correlates' to reflect the exploratory nature of our review, acknowledging that these associations do not imply causality. Furthermore, we aimed to examine publication trends, study designs, and existing knowledge gaps in mild behavioural impairment research. Our research questions were as follows:

(1) What are the correlates of mild behavioural impairment, and how are they categorized?
(2) What are the publication trends, study designs, and identified knowledge gaps in the research on mild behavioural impairment?

Methods

We conducted this scoping review in accordance with the Joanna Briggs Institute methodology [21] and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews checklist to report results [22]. The detailed protocol for our methodological approach has been published previously [23]. Ethical approval was not required, as our review was based on the published literature.

Inclusion criteria

Participants

Our review targeted studies involving older adults across the cognitive spectrum, including individuals with normal cognition, and those with subjective cognitive decline or mild cognitive impairment. The term 'older' generally refers to adults aged 60 years or older, acknowledging that the definition of 'older adults' varies by country due

to differing national standards [7]. Rather than applying a fixed age threshold, we accepted the operational definitions of "older adults" as defined in each original study.

We did not impose standardised diagnostic criteria for subjective cognitive decline or mild cognitive impairment, but instead adhered to the definitions provided by each included study. For mild cognitive impairment, the most commonly applied criteria were the Petersen/Winblad criteria [24] and the National Institute on Aging–Alzheimer's Association criteria [25]. For subjective cognitive decline, diagnostic criteria were less consistently reported. However, most studies classified participants as having subjective cognitive decline based on self-reported cognitive concerns in the absence of objective impairment, which were typically assessed using tools such as the Mini-Mental State Examination [26], Montreal Cognitive Assessment [27], or study-specific instruments. These details are summarized in Table 2.

We excluded studies that focused exclusively on individuals with diagnosed neurodegenerative diseases such as dementia, Parkinson's disease, or multiple sclerosis. However, studies that included participants with dementia as a subgroup or control group were eligible, provided that the results for non-dementia participants (e.g., those with subjective cognitive decline or mild cognitive impairment) were clearly reported. This allowed for the inclusion of relevant data while maintaining a focus on populations without overt dementia. For example, studies that reported on individuals with amnestic mild cognitive impairment due to Alzheimer's Disease as part of a broader cohort and that stratified results by diagnosis were eligible if mild behavioural impairment data for non-dementia groups were presented.

Regarding outcomes, we included studies that examined factors associated with mild behavioural impairment as a clinical syndrome, based on established definitions (e.g., Ismail et al., 2016) [13]. We did not exclude studies examining neuropsychiatric symptoms if those symptoms were analysed in the context of mild behavioural impairment diagnosis or domains, such as studies using the Mild Behavioural Impairment-Checklist or those mapping neuropsychiatric symptoms onto a mild behavioural impairment construct. However, we did exclude studies that focused only on individual neuropsychiatric symptoms (e.g., apathy or agitation) in isolation without reference to the mild behavioural impairment concept or diagnostic criteria.

Concept

This section focuses on studies that investigated the correlates and health outcomes associated with mild behavioural impairment as defined by the International Society to Advance Alzheimer's Research and Treatment–Alzheimer's Association (ISTAART-AA) criteria [13]. The emphasis is on identifying the direct factors contributing to mild behavioural impairment as well as their impacts on the health and well-being of individuals. Studies that exclusively focused on individual neuropsychiatric symptoms without linking them to the mild behavioural impairment syndrome or criteria were excluded. However, studies examining specific mild behavioural impairment domains such as apathy, impulse dyscontrol, or affective dysregulation within the context of mild behavioural impairment were included. In this review, the term "correlates" is used as a neutral and inclusive descriptor to refer to factors that are statistically associated with mild behavioural impairment, without implying directionality or causality. This usage reflects the exploratory aim of scoping reviews [21] and allows for the inclusion of a broad range of observed relationships.

Context

We placed no restrictions on the study context to capture the full range of environmental settings, using the term 'environment' as defined in previous studies to encompass both clinical and community settings [28–30]. These environments were classified as acute clinical environments, long-term care environments, and community-based environments. Acute clinical environments refer to hospital-based or inpatient settings that provide short-term, intensive medical care during episodes of medical or neuropsychiatric concern. Long-term care environments refers to residential facilities such as nursing homes or assisted living settings, and community-based environments include outpatient clinics, home settings, or community service programs that deliver ongoing or routine care rather than acute intervention. This approach ensures a comprehensive exploration of research questions related to mild behavioural impairment across different care scenarios and living situations.

Type of sources

The articles included in this review were all peer-reviewed articles published in English, incorporating a variety of research designs and observational studies. They included cohort, cross-sectional, case-control studies, experimental research, and qualitative studies. Grey literature, such as reports, theses, working papers, policy documents, government publications, and newsletters, was also reviewed to capture the broadest possible range of evidence. Books, letters, review articles, editorials, and commentaries were excluded to focus on original research and substantive findings.

Search strategy

We searched seven electronic databases, including PubMed (MEDLINE), CINAHL, PsyclNFO, EMBASE, Cochrane, SCOPUS, and Web of Science, for articles published between January 2003 and May 2024. The year 2003 was chosen as the start date because it marks the introduction of the term "mild behavioural impairment" in the literature, thereby ensuring that all relevant studies using this terminology were captured. Although our search strategy aimed to capture a wide range of studies across seven major databases, inclusion was limited to English-language publications; this may have excluded relevant findings from non-English sources. The search strategy was reviewed by a professional librarian from university's medical library. The detailed search strategies for each database are provided in Appendix A.

Study selection

Although our search included individuals with subjective cognitive decline or mild cognitive impairment who were at risk of manifesting mild behavioural impairment and developing dementia, it was not limited to these categories. Also included were individuals without any clinical diagnosis of cognitive decline. While individuals diagnosed with dementia were excluded as the primary focus, studies that included them as comparison groups, or those that presented stratified findings, were considered. This approach maximised the inclusion of relevant data on mild behavioural impairment in non-dementia populations. Given the challenge of identifying early subjective cognitive decline without concrete empirical evidence, our search parameters were designed to capture older adults who had not yet received an objective diagnosis. Studies identified in the database were selected based on a structured set of criteria aligned with the participant–concept–context framework.

Data extraction and synthesis

The retrieved articles were imported into EndNote (Clarivate Analytics, Philadelphia, Pennsylvania, USA). Abstracts and full texts were screened independently by three reviewers to ensure a thorough and unbiased selection based on the inclusion criteria. Discrepancies between reviewers were resolved through discussion, and a fourth reviewer was consulted when necessary to reach a consensus.

Following the detailed protocol developed for this review [23], the reviewers extracted key data from each selected study. Extracted data included publication year, country, study setting, design, participant demographics, types of cognitive impairment, and health outcomes reported as correlates of mild behavioural impairment. Additionally, the methodologies used to assess these correlates were documented.

To analyse the extracted data, we employed a narrative synthesis approach suitable for scoping reviews [21, 31]. Reported correlates were reviewed iteratively by three reviewers to identify patterns and thematic similarities. Through consensus discussion, the correlates were classified into three overarching categories that frequently appeared across studies: neurocognitive (e.g., biomarkers, neuroimaging findings), physical (e.g., frailty, comorbidities), and psychosocial (e.g., depressive symptoms, loneliness). These categories were not pre-specified but were developed inductively based on the content of the included studies. To be specific, correlates that shared similar characteristics or addressed related domains were grouped, which led to the emergence of the three categories in a conceptually coherent manner. Any disagreements in categorisation were resolved through consensus with the fourth reviewer.

Critical appraisal

A formal critical appraisal of the included studies was not performed, as the main goal of this scoping review was to map the evidence related to the correlates of mild behavioural impairment in older adults, rather than choosing specific evidence to address our research questions [32]. However, to support the interpretation of the results, we summarised common methodological limitations and risk of bias across the included studies in the Discussion section, focusing on factors such as design type, sample size, and outcome measurement.

Results

Search results and screening process

The initial search yielded 5,813 articles, of which 2,709 remained after duplicates were removed. After screening at the abstract level, only 301 articles remained. Full-text reviews were then conducted on these articles, with 41 meeting the inclusion criteria. Although an additional 11 articles were identified through citation searching, all of them were excluded, either because they had too narrow a focus on specific neuropsychiatric symptoms or because they had insufficient information relevant to our criteria. Therefore, the final count of included articles was 41. This selection process is illustrated in Fig. 1.

Description of the included studies

This section summarises the included studies in terms of publication trends, geographic distribution, study design, sample characteristics, and assessment tools. Table 1 provides study-level details, and Table 2 outlines participant age, cognitive status, and diagnostic criteria.

Research on mild behavioural impairment has increased since 2009, with a notable rise between 2022 and 2024. Many of the studies were conducted in North America (n = 18). One study was a multinational

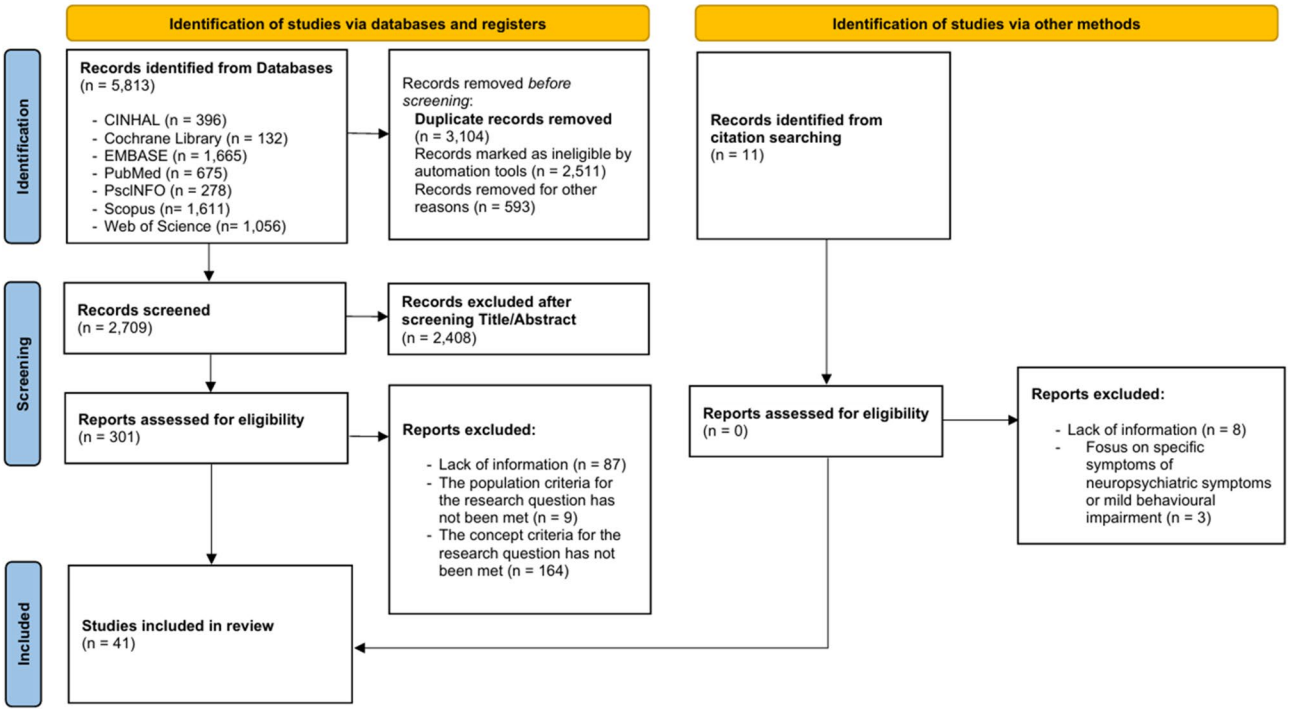

Fig. 1 PRISMA flowchart of the study selection procedure

collaboration between the United States and France (n = 1). The majority of the studies were conducted in community settings (n = 26); this was followed by clinical (n = 10) and mixed settings, and those combining clinic and community-based settings (n = 5). All studies (n = 41) used quantitative designs, primarily cross-sectional (n = 20) or longitudinal cohorts (n = 19). One study combined both [33], while another used a mixed-methods approach [34].

Sample sizes ranged widely, with the majority of studies including 100—1,000 participants (n = 22), followed by those with fewer than 100 participants (n = 7) or over 1,000 (n = 12); three studies had over 10,000 participants. Studies included participants with a range of cognitive profiles: normal cognition (n = 7), participants explicitly described as having no dementia diagnosis but with no further specification of cognitive status (n = 6), mild cognitive impairment (n = 7), or combinations of normal cognition and mild cognitive impairment (n = 10). Some studies further categorised participants into normal cognition, subjective cognitive decline, or mild cognitive impairment (n = 5), while others compared non-dementia and MCI groups (n = 3) or subjective cognitive decline and mild cognitive impairment groups (n = 2).

Common cognitive assessment tools included the Mini-Mental State Examination (n = 9), Clinical Dementia Rating (n = 7), Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (n = 3), and Montreal Cognitive Assessment (n = 1). Diagnostic frameworks included the Petersen/Winblad criteria (n = 11), National Institute of Aging and Alzheimer's Association framework (n = 5), Comprehensive Assessment of Neurodegeneration and Dementia criteria (n = 4), and National Institute of Neurological and Communicative Diseases and Stroke/Alzheimer's Disease and Related Disorders Association criteria (n = 4).

Several measurement tools were used to assess mild behavioural impairment. The Neuropsychiatric Inventory Questionnaire, a streamlined, information-based version of the Neuropsychiatric Inventory, was the most frequently used (n = 14) [35, 36]. The Neuropsychiatric Inventory, utilised in five studies, evaluates a range of symptoms, including delusions, hallucinations, and agitation, with its domains potentially corresponding to the five subcategories of mild behavioural impairment: diminished motivation, mood disturbance, irritability, impaired social behaviour, and abnormal perception [13]. Two studies utilised both the Neuropsychiatric Inventory and the Neuropsychiatric Inventory Questionnaire [37, 38]. Seventeen studies employed the Mild Behavioural Impairment-Checklist, which includes 34 items that capture five domains of mild behavioural impairment:

Table 1 Profiles of the included studies

Variables	Categories	*n* (%)
Publication year	2009	1 (2)
	2018–2019	7 (17)
	2020–2021	13 (32)
	2022–2024	20 (49)
Country	North America (USA, Canada)	18 (44)
	Asia (including China, Japan, Singapore, South Korea)	12 (29)
	Europe (including Czech Republic, Spain, Sweden, UK)	6 (15)
	Other countries (Argentina, Australia, North America, and France)	5 (12)
Study settings	Community	26 (63)
	Clinic	10 (24)
	Community and clinic	5 (12)
Sample size	34–99	7 (17)
	100–999	22 (53)
	1,000–9,999	9 (22)
	10,000–17,291	3 (7)
Targeted participants	CN	7 (17)
	Non-dementia	6 (15)
	MCI	7 (17)
	CN and MCI	10 (24)
	CN and SCD and MCI	5 (12)
	Other groups (non-dementia and MCI, SCD and MCI, CN, MCI, and Dementia)	6 (15)
Diagnostic tools and criteria for cognitive status†	MMSE	9 (22)
	CDR	7 (17)
	DSM-5	3 (7)
	MOCA	1 (2)
	Petersen/Winblad criteria	11 (27)
	NIA-AA	5 (12)
	COMPASS-ND	4 (10)
	NINCDS-ADRDA	4 (10)
MBI measurement tools	NPI	5 (12)
	NPI-Q	14 (34)
	NPI or NPI-Q	2 (5)
	MBI-C	17 (41)
	Specified criteria used in individual studies	3 (7)
Study design	Cross-sectional study	20 (49)
	Longitudinal study	19 (46)
	Cross-sectional and longitudinal study	1 (2)
	Mixed method study (RCT and qualitative study)	1 (2)

CDR Clinical Dementia Rating Scale, *CN* Cognitive Normal, *COMPASS-ND* Comprehensive Assessment of Neurodegeneration and Dementia, *DSM-5* Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, *MBI* Mild Behavioral Impairment, *MBI-C* Mild Behavioral Impairment Checklist, *MCI* Mild Cognitive Impairment, *MMSE* Mini-Mental State Examination, *MoCA* Montreal Cognitive Assessment, *NIA-AA* National Institute of Aging and Alzheimer's Association, *NINCDS-ADRDA* National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association, *NPI* Neuropsychiatric Inventory, *RCT* Randomized Control Trial, *SCD* Subjective Cognitive Decline

† The total count exceeds the number of included studies ($N=41$) because several studies employed more than one diagnostic tool or criterion to assess cognitive status

decreased motivation, affective dysregulation, impulse dyscontrol, social inappropriateness, and abnormal perception or thought content. This checklist represents the most commonly used single tool across the included studies. Three studies did not use a specific instrument to diagnose mild behavioural impairment, but instead relied on self-reports by older adults or caregivers in conjunction with clinician judgment, and based on the formal definition of mild behavioural impairment [14, 15, 39].

Correlates of mild behavioural impairment

Correlates of mild behavioural impairment were classified into three categories—neurocognitive, physical, and psychosocial—based on a structured descriptive synthesis of the findings from included studies. This classification was guided by the conceptual framework of mild behavioural impairment [13], which consists of five behavioural domains: decreased motivation, affective dysregulation, impulse dyscontrol, social inappropriateness, and abnormal perception or thought content. While the original studies varied in design and terminology, we categorised their findings into these three broader domains according to the type of correlates they reported and to their alignment with the recognised mild behavioural impairment symptom structure [13]. Table 3 presents these categories along with the relevant findings from the reviewed studies. Most studies focused on neurocognitive aspects (n = 31), exploring the relationship between mild behavioural impairment symptoms and variables. Examples include genetic risk, brain atrophy, and progression to functional decline. Some studies examined physical correlates and investigated how mild behavioural impairment is related to physical health (n = 9), with topics including geriatric syndromes, conditions such as hearing loss or head injuries, and chronic conditions. Additionally, a few studies addressed psychosocial correlates (n = 5), including depressive symptoms, loneliness, quality of life, caregiver burden, and the influence of psychobehavioural programs.

Neurocognitive correlates of mild behavioural impairment

Research on mild behavioural impairment has predominantly focused on neurocognitive factors. These factors can be broadly categorised into two main groups: biomarkers, and progression to cognitive and functional decline. This classification is based on shared conceptual features and guided by prior literature highlighting distinct biological and functional markers relevant to mild behavioural impairment [40]. Several cross-sectional studies have identified key biomarkers associated with the presence and severity of mild behavioural impairment. These include genetic factors, such as the apolipoprotein E e4 allele, and polygenic risk scores. For example, Andrews et al. (2018) found that an elevated

Table 2 Participant characteristics in the included studies ($N=41$)

Author (year)	Country	Setting	Sample characteristics			
			Age (mean, range)	Sample size (*N*)	Cognitive status (*n*)	Measure or diagnostic criteria for cognitive status
Neurocognitive correlates						
Andrews et al. (2018)	Australia	Community	75.0, 72–79	1,226	1) CN (1,115) 2) MCI (111)	PATH diagnosis criteria, MMSE, MAC-Q, DSM-5, DSM-IV, Petersen/Winblad criteria
Creese et al. (2019)	UK	Community	62.0, NR	9,931	CN (9,931)	PROTECT Study diagnosis criteria
Creese et al. (2021)	UK	Community	63.5, NR	4,458	CN (4,458)	PROTECT Study diagnosis criteria
Ghahremani et al. (2023a)	USA and Canada	Community	72.2, 55–90	571	1) CN (201) 2) MCI (370)	ANDI diagnosis criteria
Ghahremani et al. (2023b)	Canada	Community	71.7, NR	95	1) CN (60) 2) MCI (35)	FAVR, COMPASS-ND
Ismail et al. (2021)	USA	Community	76.0, NR	2,769	Non-dementia (2,769)	NACC-UDS diagnosis, CDR
Ismail et al. (2023)	USA, Canada, and France	Community	71.7, NR	510	MCI (510)	NIA-AA criteria
Johansson et al.(2021)	Sweden	Community	72.3, 44–88	50	CN (50)	NIA-AA criteria
Kan et al. (2022)	Singapore	Clinic & Community	72.2, NR	304	Non-dementia (304)	MMSE, the National Institute of Neurologic Disorders and Stroke and Canadian Stroke Network protocol
Ruthirakuhan et al. (2023)	USA	Community	67, NR	499	Non-dementia (499)	NR
Lussier et al. (2020)	Canada	Community	71.5, 57–85	96	CN (96)	MRI, β-amyloid and tau PET, genotyping for APOEε4.
Matsuoka et al. (2019)	Japan	Clinic	68.9, NR	2,853	1) CN (2,622) 2) SCD (51) 3) MCI (180)	Dementia with Lewy bodies consensus criteria, Petersen/Winblad criteria
Matsuoka et al. (2021)	Japan	Clinic	76.9, NR	43	1) CN (30) 2) MCI (13)	Petersen/Winblad criteria, CDR
Matuskova et al. (2021)	Czech	Clinic	69.6, NR	116	1) SCD (37) 2) MCI (79)	Petersen/Winblad criteria, NIA-AA criteria
McGirr et al. (2022)	USA	Community	75.2, NR	739	MCI (739)	NACC-UDS diagnosis
Miao et al. (2021)	France	Community	72.8, NR	768	MCI (768)	CDR, MMSE, Petersen/Winblad criteria
Miao et al. (2022)	USA	Community	72.4, 55–90	139	1) CN (53) 2) MCI (86)	MMSE, ADNI diagnosis criteria
Naude et al. (2020)	USA	Community	74.3, 55–93	584	Non-dementia (584)	ADNI diagnosis criteria
Naude et al. (2024)	USA	Community	74.8, NR	442	1) CN (283) 2) MCI (157)	MMSE, CDR, Memory Box Score
Rouse et al. (2024) [†]	USA	Community	72.1, NR	17,291	1) CN (11,771) 2) MCI (5,520)	NACC-UDS diagnosis, Petersen/Winblad criteria
Ruthirakuhan et al. (2022)	USA	Community	70.5, NR	11,372	CN (11,372)	NINCDS-ADRDA criteria (before 2015), NIA-AA criteria (after 2015)
Shu et al. (2021)	China	Clinic	67.0, NR	34	CN (34)	MMSE

Table 2 (continued)

Author (year)	Country	Setting	Sample characteristics			
			Age (mean, range)	Sample size (*N*)	Cognitive status (*n*)	Measure or diagnostic criteria for cognitive status
Sun et al. (2021)	North America	Community	72.1, NR	1,129	1) CN (586) 2) MCI (543)	ANDI criteria
Taragano et al. (2009)	Argentina	Community	72.5, NR	358	1) MCI (239) 2) Non- dementia and non-MCI (119)	DSM-IV
Taragano et al. (2018)	Argentina	Clinic	71.2, NR	348	1) MCI (87) 2) Non-dementia and non-MCI (261)	CDR
Tsunoda et al. (2021)	Japan	Clinic	71.1, NR	76	CN (76)	MMSE, CDR
Wolfova et al. (2022)	UK	Community	63.0*, NR	8,181	Non-dementia (8,181)	PROTECT Study diagnosis criteria
Yokoi et al. (2019)	Japan	Community	72.8, NR	234	MCI (234)	J-ADNI criteria, NINCDS-ADRDA criteria
Yoon et al. (2023)	South Korea	Clinic & Community	73.5, 60–80	1,184	MCI (1,184)	NINCDS-ADRDA criteria, Petersen/Winblad criteria
Physical correlates						
Fan et al. (2020)	China	Clinic	69.6, 60–90	137	Non-dementia (137)	MMSE
Gosselin et al. (2022)	Canada	Clinic & Community	72.2, 50.2–87.1	219	1) CN (10) 2) SCD (48) 3) MCI (161)	COMPASS-ND
Gosselin et al. (2023)	USA	Community	71.6, 50–100	7,080	1) CN (4,926) 2) SCD (381) 3) MCI (1,773)	NACC-UDS diagnosis
Guan et al. (2022a)	Canada	Clinic & Community	72.4, NR	193	1) CN (10) 2) SCD (48) 3) MCI (135)	COMPASS-ND
Guan et al. (2022b)	Canada	Clinic & Community	72.2, 50.2–87.1	219	1) CN (10) 2) SCD (48) 3) MCI (161)	COMPASS-ND
Richey et al. (2023)	USA	Community	75.8, NR	2,534	1) CN (1,309) 2) MCI (961) 3) Dementia (264)	NIA-AA criteria, DSM-5, MMSE, CDR, TICS-M
Soo et al. (2021)	Singapore	Community	66.7, NR	172	1) CN (79) 2) MCI (93)	Petersen/Winblad criteria, NIA-AA criteria
Psychosocial category						
Lin et al. (2023)	Hong Kong	Community	69.1, NR	171	MCI (171)	MoCA
Matsuoka et al. (2024)	Japan	Community	80, NR	80	1) CN (5) 2) MCI (75)	Petersen/Winblad criteria
Sheikh et al. (2018)	Canada	Clinic	62.0, 55–66	282	1) SCD (119) 2) MCI (163)	Petersen/Winblad criteria
Neurocognitive & Psychosocial						
Mallo et al. (2018)	Spain	Community	70.0, 50–84	111	MCI (111)	DSM-5, NINCDS-ADRDA criteria
Tsai et al. (2023)	Taiwan	Clinic	71.6, NR	242	1) MCI (129) 2) Non-dementia and non-MCI (113)	Petersen/Winblad criteria

AD Alzheimer's disease, *ADAS* Alzheimer's Disease Assessment Scale, *ANDI* Alzheimer's Disease Neuroimaging Initiative, *APOE ε4* ε4 allele of the Apolipoprotein E, *CDR* Clinical Dementia Rating Scale, *CN* Cognitive Normal, *COMPASS-ND* Comprehensive Assessment of Neurodegeneration and Dementia, *DSM-IV* Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, *DSM-5* Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, *FAVR* Functional Assessment of Vascular Reactivity, *J-ANDI* Japanese prospective cohort from the Alzheimer's Disease Neuroimaging Initiative, *MAC-Q* Memory Assessment Clinic- Questionnaire, *MCI* Mild Cognitive Impairment, *MMSE* Mini-Mental State Examination, *MoCA* Montreal Cognitive Assessment, *MRI* Magnetic Resonance Imaging, *NACC-UDS* National Alzheimer's Coordinating Canter's uniform data set, *NIA-AA* National Institute of Aging and Alzheimer's Association, *NINCDS-ADRDA* National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association, *NR* not reported, *PATH* Personality and Total Health Through Life, *PET* Positron Emission Tomography, *SCD* Subjective Cognitive Decline

* Median age

† The digital publication year is 2023, while the journal's official publication date is 2024

Table 3 A summary of the design and relevant findings of reviewed studies

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Neurocognitive correlates					
Andrews et al. (2018)	Cross-sectional	NPI (NPI > 0)	Domain-specific -Presence	Biomarkers (genetic risk)	• Presence of the MBI domain, affective dysregulation, was associated with an elevated genetic risk score and the presence of the APOE*ε4 allele. • Presence of the other MBI domains (decreased motivation, impulse dyscontrol, social inappropriateness, and abnormal perception or thought control) was not associated with genetic risk score and the presence of the APOE*ε4 allele.
Ghahremani et al. (2023b)	Cross-sectional	MBI-C (≥ 6)	Global MBI -Presence	Biomarkers (functional connectivity)	• Presence of MBI was associated with reduced functional connectivity in the medial prefrontal cortex (default mode network) and left anterior insula (salience network).
Johansson et al. (2021)	Cross-sectional	MBI-C (NR)	Global MBI -Severity	Biomarkers (PET biomarker)	• Greater MBI symptom severity was associated with higher tau-PET SUVR and increased cerebrospinal fluid P-tau181 levels.
Lussier et al. (2020)	Cross-sectional	MBI-C (8.5)	Global MBI -Presence	Biomarkers (PET biomarker)	• Presence of MBI was positively associated with higher β-amyloid burden, indicated by increased 18 F-AZD4694 SUVR. • Presence of MBI was positively associated with increased Tau burden, as shown by higher 18 F-MK6240 SUVR.
Matsuoka et al. (2021)	Cross-sectional	MBI-C (6.5)	Global MBI -Severity	Biomarkers (Functional connectivity)	• Greater MBI symptom severity was associated with a decrease in functional connectivity between the left posterior parietal cortex and the right middle frontal gyrus.
			Domain-specific MBI-Presence		• Presence of the MBI domain, affective dysregulation, was associated with a decrease in functional connectivity between the left posterior parietal cortex and the right middle frontal gyrus. • Presence of MBI domains (decreased motivation and impulse dyscontrol, social inappropriateness, and abnormal perception or thought control) were not associated with functional connectivity.
Matuskova et al. (2021)	Cross-sectional	MBI-C (NR)	Domain-specific MBI- Severity	Biomarkers (Brain atrophy)	• Greater severity of MBI symptoms, globally and particularly in MBI domains (impulse dyscontrol and decreased motivation) was associated with increased atrophy in medial temporal lobe regions, notably the entorhinal cortex and hippocampus volume. • Severity of MBI domains (affective dysregulation, social inappropriateness, and abnormal perception or thought control) was not associated with atrophy in the medial temporal lobe.
Miao et al. (2021)	Cross-sectional	NPI (NPI > 0)	Global MBI -Presence	Biomarkers (Brain atrophy)	• Presence of MBI was positively associated with higher brain atrophy of white matter, indicated by increased white matter hyperintensity volume.
			Domain-specific MBI-Presence		• None of the MBI domains were associated with greater white matter hyperintensity volume.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Miao et al. (2022)	Cross-sectional	NPI (NPI > 0)	Global MBI -Severity Domain-specific MBI-Severity	Biomarkers (plasma biomarker)	• Greater severity of MBI symptoms was associated with lower plasma Aβ42/Aβ40 levels. • Greater severity of MBI symptoms in MBI domain (affective dysregulation) was associated with lower plasma Aβ42/Aβ40 levels. (Analysis was precluded for abnormal thoughts and social inappropriateness due to their low frequency.)
Naude et al. (2020)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Biomarkers (plasma biomarker)	• Presence of MBI was associated with changes in neurofilament light concentrates, with the significance of this association interacting with time.
Naude et al. (2024)	Cross-sectional	NPI (NPI > 0)	Global MBI -Presence	Biomarkers (PET biomarker)	• Presence of MBI was positively associated with a higher tau accumulation, indicated by increased AV1451 SUVR in Braak regions among Aβ positive individuals.
Shu et al. (2021)	Cross-sectional	MBI-C (> 8)	Global MBI -Presence, Severity	Biomarkers (brain atrophy)	• Presence of MBI was associated with grey matter atrophy; increased atrophy was observed in multiple brain regions. • Greater severity of MBI symptoms was associated with a reduction in grey matter volume.
Creese et al. (2019)	Longitudinal	MBI-C (≥ 8)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with decline in the scores of four tasks of the CogTrack system (attentional intensity, sustained attention, attentional fluctuation, and working memory) and 12 tasks of the PROTECT Cognitive Assessment (grammatical reasoning accuracy, simple reaction time, digit vigilance accuracy, digit vigilance speed, digit vigilance false alarms, digit vigilance, choice reaction time accuracy, choice reaction time speed, choice reaction time, paired associate learning, self-ordered search, and verbal reasoning). • Presence of MBI was not associated with seven tasks of the PROTECT Cognitive Assessment (grammatical reasoning speed, simple reaction time speed, all four pattern separation tests [original stimuli accuracy, original stimuli median speed, novel stimuli accuracy, novel stimuli median speed], and digit span).
Ismail et al. (2021)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive and functional decline and progression to dementia)	• Presence of MBI increased the risk of progressing to dementia. • MBI with SCD had a higher risk of progressing to dementia (CDR > 0), indicating increased cognitive and functional decline.
Kassam et al. (2023)	Longitudinal	MBI-C (7)	Global MBI -Presence, Severity	Progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with poorer memory and executive function. • Presence of MBI was not associated with the number of errors and response time on the Go/No-Go task. • Greater MBI symptom severity was associated with poorer performance in memory and executive function.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Mallo et al. (2018)	Cross-sectional	MBI-C (6.5)	Global MBI -Severity	Progression to cognitive and functional decline (IADL decline)	• Greater MBI symptom severity was associated with higher dependence in instrumental activities of daily living.
Matsuoka et al. (2019)	Longitudinal	MBI-C (NR)	Global MBI -Presence	Progression to cognitive and functional decline (progression to dementia)	• Presence of MBI was associated with shorter time until dementia onset.
Kan et al. (2022)	Longitudinal	NPI (NPI > 0)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with global cognition decline, affecting memory, attention, language, and worsening cognitive or functional status.
McGirr et al. (2022)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Progression to cognitive and functional decline (progression to AD and cognitive function decline)	• Presence of MBI increased the risk of dementia progression and lowered the chance of reverting to normal cognitive function. • The simultaneous occurrence of MBI and MCI was associated with a greater risk of cognitive decline, with individuals showing MBI having lower cognitive function.
Rouse et al. (2024)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with lower cognitive function across attention, episodic memory, executive function, language, visuospatial ability, and processing speed domains. • Presence of MBI was associated with lower visuospatial ability, with the significance of this association interacting with MCI status.
Ruthirakuhan et al. (2022)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Progression to cognitive and functional decline (progression to AD)	• Presence of MBI was associated with an increased risk of progressing to clinically diagnosed AD and neuro-pathologically confirmed AD.
			Domain-specific MBI-Presence		• Presence of specific MBI domains associated with clinically diagnosed AD, with psychosis showing the most significant impact, followed by social inappropriateness, impulse dyscontrol, decreased motivation, and emotional dysregulation.
Taragano et al. (2009)	Longitudinal	Specified criteria delineated by researcher	Global MBI -Presence	Progression to cognitive and functional decline (progression to dementia)	• Presence of MBI was associated with higher risk and earlier onset of dementia.
Taragano et al. (2018)	Longitudinal	Specified criteria delineated by researcher	Global MBI -Presence	Progression to cognitive and functional decline (progression to dementia)	• Presence of MBI was associated with higher risk of progression to dementia.
Tsai et al. (2023)	Cross-sectional	MBI-C (7.5)	Global MBI -Severity	Progression to cognitive and functional decline (cognitive function decline, IADL decline)	• Greater MBI symptom severity was associated with poorer language performance. • Greater severity of MBI symptoms was correlated with higher dependence in instrumental activities of daily living.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Tsunoda et al. (2021)	Longitudinal	MBI-C (8.5)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with increased cognitive and functional decline. • Presence of MBI was not associated with changes in cognitive function.
Wolfova et al. (2022)	Longitudinal	MBI-C (> 8)	Global MBI -Presence	Progression to cognitive and functional decline (cognitive function decline and progression to dementia)	• Across genders, presence of MBI was associated with a decline in self-ordered search and verbal reasoning. • In males, presence of MBI was associated with decreased cognitive function decline.
			Domain-specific MBI-Presence		• In males, the presence of MBI domains (decreased motivation, impulse dyscontrol, social inappropriateness, and psychotic symptoms) was associated with faster decline in verbal reasoning, while other MBI domain (emotional dysregulation) was associated with faster cognitive decline. • In females, presence of MBI domains (emotional dysregulation, decreased motivation, and impulse dyscontrol) was associated with faster decline in verbal reasoning, while other MBI domains (social inappropriateness and psychotic symptoms) were not associated with cognitive decline. • Presence of MBI domains (abnormal perception and thought domain) was associated with a higher risk of progression to dementia. • The other MBI domains (emotional dysregulation domain, decreased motivation, affective dysregulation, impulse dyscontrol, and social inappropriateness) were not associated with a higher risk of progression to dementia.
Yokoi et al. (2019)	Longitudinal	NPI-Q (NPI > 0)	Domain-specific MBI -Presence, Severity	Progression to cognitive and functional decline (global cognitive function decline)	• Presence of MBI domains (decreased motivation) was associated with poorer cognitive. • Greater severity of MBI symptoms in decreased motivation and affective dysfunction was positively associated with poorer performance in global cognitive function. • Presence of MBI domains (impulse dyscontrol, social inappropriateness, and abnormal perception or thought) was not associated with the ADAS.
Creese et al. (2021)	Cross-sectional	MBI-C (≥ 6)	Global MBI -Presence	Biomarkers (genetic risk score), progression to cognitive and functional decline (cognitive function decline)	• Presence of MBI was associated with increased AD polygenic risk and decreased cognitive function.
Ghahremani et al. (2023a)	Longitudinal	NPI or NPI-Q (NPI > 0)	Global MBI -Presence	Biomarkers (plasma biomarker), progression to cognitive and functional decline (cognitive function decline and Incident dementia)	• Presence of MBI was associated with an increase in plasma p-tau 181 levels. • Presence of MBI was associated with decreased cognitive function. • Presence of MBI was associated with shorter dementia-free survival and higher dementia risk.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Ismail et al. (2023)	Cross-sectional & Longitudinal	NPI or NPI-Q (NPI > 0)	Global MBI -Presence	Biomarkers (cerebrospinal fluid biomarker), progression to cognitive and functional decline (incident dementia)	• Presence of MBI was associated with lower Aβ42, and Aβ42/40 ratios; higher p-tau, t-tau, and ratio of p-tau/Aβ42 and t-tau/Aβ42. • Presence of NPS without MBI was only associated with increased t-tau. • Presence of MBI without NPS was associated with lower Aβ42, higher p-tau, and increased ratios of p-tau/Aβ42 and t-tau/Aβ42. MBI associated with a higher incidence of dementia.
Sun et al. (2021)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Severity	Biomarkers (PET biomarker), progression to cognitive and functional decline (cognitive function decline)	• Greater severity of MBI symptoms was associated with increased β-amyloid burden and decreased 18 F-fluorodeoxyglucose PET uptake. • Greater severity of MBI symptoms was associated with lower performance in global cognitive measures, including MMSE, MoCA, and ADAS.
Yoon et al. (2023)	Longitudinal	NPI-Q (NPI > 0)	Domain-specific MBI- Severity	Progression to cognitive and functional decline (progression to AD)	• Greater severity of MBI symptoms in each domain was associated with higher risk of progression to AD.
			Global MBI -Presence	Biomarkers (brain Atrophy), progression to cognitive and functional decline (progression to AD)	• Presence of MBI was associated with increased cortical thinning in the inferior parietal cortex, lateral occipital cortex, lateral superior temporal gyrus, and frontopolar cortex, along with thinning in the left superior frontal sulcus, left cuneus, and right middle frontal gyrus. • Presence of MBI was associated with a higher risk of progressing to AD.
Physical correlates					
Fan et al. (2020)	Cross-sectional	MBI-C (> 8)	Global MBI - Severity Domain-specific MBI-Presence	Geriatric syndromes (frailty)	• Greater severity of MBI symptoms was associated with higher risk of frailty. • Presence of MBI domains (decreased motivation, affective dysregulation, and social inappropriateness) was associated with higher risk of frailty. • The other MBI domains (impulse dyscontrol and psychosis) were not associated with a risk of frailty.
Guan et al. (2022a)	Cross-sectional	NPI-Q (NPI > 0)	Global MBI -Severity	Geriatric syndromes (gait speed, dual-task gait cost)	• Greater severity of global MBI symptoms was associated with reduced gait speed. • Greater severity of global MBI symptoms was associated with higher dual-task gait cost.
Guan et al. (2022b)	Cross-sectional	NPI-Q (NPI > 0)	Global MBI -Severity	Geriatric syndromes (frailty)	• Greater severity of global MBI symptoms was associated with a worsened frailty status. • Gender moderated this relationship, with males exhibiting greater severity of MBI symptoms at medium and high levels of the frailty status.
			Domain-specific MBI -Presence		• Presence of MBI domains (decreased motivation, affective dysregulation, and psychosis) was associated with worsened frailty status.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Gosselin et al. (2022)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence, Severity	Acquired physical conditions (hearing loss)	• Presence of MBI was not associated with objective measures in hearing loss, such as speech-in-noise thresholds, audiometric hearing loss, and hearing aid use. • Greater severity of global MBI symptoms was associated with poorer hearing function.
			Domain-specific MBI-Presence		• Presence of MBI domain, apathy, and affective dysregulation was associated with poorer hearing function. • The other MBI domains (impulse dyscontrol, social inappropriateness, and psychosis) were not associated with hearing function.
Gosselin et al. (2023)	Longitudinal	NPI-Q (NPI > 0)	Global MBI -Presence	Acquired physical conditions (hearing loss)	• Presence of MBI was associated with a higher likelihood of status with untreated-hearing loss (not using hearing aids). • Presence of MBI was associated with untreated-hearing loss (not using hearing aids) compared to those without hearing loss. • Incidence of MBI was associated with treated-hearing loss (using hearing aids) compared to those without hearing loss. • Incidence of MBI was not associated with untreated-hearing loss (not using hearing aids), compared to those without hearing loss.
			Domain-specific MBI-Presence		• Presence of MBI domains (social inappropriateness, affective dysregulation, and impulse dyscontrol) was associated with untreated-hearing loss compared to those without hearing loss. • Presence of MBI domains (decreased motivation and abnormal perception) was not associated with the presence of untreated-hearing loss or those without hearing loss.
Richey et al. (2023)	Longitudinal	NPI-Q (NPI > 0)	Domain-specific MBI-Severity	Acquired physical conditions (head injuries)	• Greater severity of MBI domains (affective dysregulation and impulse dyscontrol) was associated with a history of two or more head injuries. • Greater severity of MBI domains (decreased motivation, social inappropriateness, and abnormal perception or thought control) was not associated with a history of head injuries.
Soo et al. (2021)	Cross-sectional	MBI-C (> 6.5)	Global MBI -Presence, Severity	Chronic conditions (prevalence of diabetes mellitus)	• Presence of MBI was associated with an increased prevalence of diabetes mellitus. • Greater severity of MBI symptoms was associated with a higher prevalence of diabetes mellitus. This relationship became more pronounced after including interaction terms with MCI compared to CN cohorts.
			Domain-specific MBI-Severity		• Presence of MBI specific domains (decreased motivation, emotional dysregulation, impulse dyscontrol, and abnormal thoughts) was associated with a higher prevalence of diabetes mellitus. • Severity of MBI domain (social inappropriateness) was not associated with the prevalence of diabetes mellitus.

Table 3 (continued)

Author (year)	Design	MBI measure		Relevant findings	
		Instrument (cut-off score)	Assessment target	Correlates	Main results
Psychosocial correlates					
Lin et al. (2023)	Mixed methods (single-blinded randomized controlled trial and descriptive qualitative study)	MBI-C (6.5)	Global MBI -Presence	Educational intervention (psychobehavioral program)	• Presence of MBI was associated with a reduction in overall NPS and an improvement in cognitive function after involvement in an educative psycho-behavioral program intervention. • Presence of MBI was not associated with improvement of health-related quality of life after involvement in an educative psycho-behavioral program intervention. • Qualitative data indicated that the psycho-behavioral program improved coping strategies for managing daily hassles and emotional arousal.
Sheikh et al. (2018)	Cross-sectional	NPI-Q (NPI > 0)	Global MBI -Presence, Severity	Psychosocial health and well-being (caregiver burden)	• Presence of MBI was associated with higher caregiver burden. • Greater severity of MBI symptoms was associated with elevated caregiver burden.
Mallo et al. (2018)	Cross-sectional	MBI-C (6.5)	Global MBI -Severity	Psychosocial health and well-being (depressive symptom)	• Greater MBI symptom severity was associated with depressive symptoms.
Matsuoka et al. (2024)	Cross-sectional	ISTAART research diagnostic criteria	Global MBI -Severity Domain-specific MBI-Severity	Psychosocial health and well-being (loneliness)	• Greater MBI symptom severity was associated higher loneliness level. • Severity of MBI domains (decreased motivation, affective dysregulation, abnormal thought and perception) was associated with higher loneliness level.
Tsai et al. (2023)	Cross-sectional	MBI-C (7.5)	Global MBI -Severity Domain-specific MBI-Presence	Psychosocial health and well-being (quality of life and depressive symptom)	• Greater severity of MBI symptoms was associated with decreased level of health-related quality of life. • Presence of MBI domains (decreased motivation and emotional dysregulation) was associated with decreased health related quality of life. • Greater severity of MBI symptoms was associated with depressive symptoms.

AD Alzheimer's disease, *ADAS* Alzheimer's Disease Assessment Scale, *APOE ε4* ε4 allele of the Apolipoprotein E, *CDR* Clinical Dementia Rating Scale, *CDR-SoB* Clinical Dementia Rating Sum of Boxes, *CN* Cognitive Normal, *DSM-5* Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, *FI* Frailty Index, *GDS-15* 15-item Geriatric Depression Scale, *IADL* Instrumental Activity of Daily Living, *ISRAART* International Society to Advance Alzheimer's Research and Treatment, *RAVLT* Rey Auditory Verbal Learning Test, *MBI* Mild Behavioural Impairment, *MBI-C* Mild Behavioural Impairment Checklist, *MCI* Mild Cognitive Impairment, *MMSE* Mini-Mental State Examination, *MoCA* Montreal Cognitive Assessment, *MRI* Magnetic Resonance Imaging, *NPI* Neuropsychiatric Inventory, *NPI-Q* Neuropsychiatric Inventory–Questionnaire, *NR* not reported, *PET* Positron Emission Tomography, *SUVR* Standardized Uptake Value Ratio, *SCD* Subjective Cognitive Decline, *ZCBS* Zarit Caregiver Burden Scale

genetic risk score and the presence of the apolipoprotein E e4 allele were linked to symptoms of affective dysregulation, a domain of mild behavioural impairment [41]. Similarly, Creese et al. (2021) reported that an increased polygenic risk of Alzheimer's disease was associated with global mild behavioural impairment symptoms [42].

Functional connectivity has also been studied in relation to mild behavioural impairment, with reduced connectivity in specific brain regions correlating with both the presence and severity of symptoms of mild behavioural impairment in cross-sectional studies. Ghahremani et al. (2023b) found that global mild behavioural impairment symptoms were associated with reduced functional connectivity in the medial prefrontal cortex and left anterior insula [38]. Additionally, Matsuoka et al. (2021) found that decreased connectivity between the left posterior parietal cortex and right middle frontal gyrus was associated with the presence of domain-specific mild behavioural impairment symptoms such as affective dysregulation as well as greater severity of global mild behavioural impairment symptoms [43].

PET biomarker studies have revealed that higher β-amyloid burden, increased tau-accumulation, and specific cerebrospinal fluid biomarkers, such as lower Aβ42 and Aβ42/Aβ40 ratios, as well as higher p-tau and t-tau levels, are associated with the presence of global mild behavioural impairment symptoms [33, 44, 45]. Moreover, Johansson et al. (2021) and Sun et al. (2021) have linked higher tau-PET SUVR, increased cerebrospinal fluid p-tau181 levels, increased β-amyloid burden, and decreased 18 F-fluorodeoxyglucose PET uptake to greater severity of global mild behavioural impairment symptoms [46, 47].

Brain atrophy has consistently been associated with mild behavioural impairment in cross-sectional studies. Studies have shown that the presence of global mild behavioural impairment is associated with increased white and grey matter atrophy [48, 49]. Indeed, a greater severity of global mild behavioural impairment is related to reduced grey matter volume [49]. Matsuoka et al. (2021) reported that atrophy in the medial temporal lobe regions, particularly in the entorhinal cortex and hippocampus, is related to a greater severity of mild behavioural impairment, particularly in domains such as impulse dyscontrol and decreased motivation [43].

Plasma biomarkers have also been linked to mild behavioural impairment in cross-sectional evidence. Changes in neurofilament light concentrations and increased plasma p-tau 181 levels are associated with global mild behavioural impairment symptoms [37, 50]. Further, lower plasma Aβ42/Aβ40 levels have been related to greater severity of global mild behavioural impairment symptoms and specific domains such as affective dysregulation [51].

In addition to biomarkers, numerous longitudinal studies have shown that progression to cognitive decline and functional impairment have been associated with the presence and severity of mild behavioural impairment symptoms. Previous studies have demonstrated that both the presence and severity of global mild behavioural impairment symptoms are related to cognitive decline [37, 42, 47, 52–58]. This progression has also been linked to greater dependence on the instrumental activities of daily living [17, 56].

Furthermore, the presence of mild behavioural impairment symptoms in specific domains, such as decreased motivation, and greater severity in domains, such as affective dysregulation, has been associated with poorer cognitive performance [59]. Wolfova et al. (2022) observed gender-specific patterns in this progression [58]. Males exhibit a more pronounced cognitive decline in domains such as impulse dyscontrol and psychotic symptoms, while females experience a faster decline in domains such as emotional dysregulation and decreased motivation [58].

Finally, the presence of global mild behavioural impairment symptoms is associated with an increased risk of progression to dementia in longitudinal studies [4, 15, 20, 33, 38, 60]. Studies have shown that the presence of global mild behavioural impairment symptoms is linked to an earlier onset of dementia [15, 61] and shorter dementia-free survival [38]. Additionally, individuals with subjective cognitive decline and the presence of global mild behavioural impairment symptoms have shown a higher risk of progression to dementia [4], whereas those with mild cognitive impairment and the presence of global mild behavioural impairment symptoms exhibit a greater risk of cognitive decline [60]. The presence of mild behavioural impairment symptoms in specific domains, such as social inappropriateness, impulse dyscontrol, decreased motivation, and emotional dysregulation, has been associated with a higher risk of clinically diagnosed Alzheimer's disease [20]. Similarly, abnormal perceptions and thoughts are associated with a higher risk of dementia progression [58]. Greater severity of mild behavioural impairment in each domain has also been linked to an increased risk of Alzheimer's disease progression [62].

Physical correlates of mild behavioural impairment

The relationship between mild behavioural impairment and various physical health conditions has been explored in several studies. The physical correlates include frailty, hearing loss, gait speed, head injury, and diabetes mellitus.

Frailty was categorised under physical correlates based on how it was operationalised in the included studies. Most studies assessed frailty using physical performance measures such as grip strength, walking speed, fatigue, and physical activity, rather than cognitive or oral components. Thus, this classification reflects the physical emphasis of the original definitions used in the primary studies.

In terms of frailty and gait speed, these two geriatric syndromes have been studied in relation to the presence and severity of mild behavioural impairment symptoms. Cross-sectional and longitudinal evidence has shown that a higher risk of frailty is linked to greater severity of global mild behavioural impairment symptoms. For example, Fan et al. (2020) and Guan et al. (2022b) found that individuals with higher levels of frailty tended to have more severe global mild behavioural impairment symptoms [63, 64]. This relationship is also significant in the presence of specific domains of mild behavioural impairment symptoms such as decreased motivation and affective dysregulation [63, 64].

Additionally, Guan et al. (2022b) reported that males with medium to high levels of frailty showed more severe mild behavioural impairment symptoms [64]. Gait speed has also been associated with symptoms of mild

behavioural impairment in a prospective cohort study. Guan et al. (2022b) found that a reduction in gait speed was related to a greater severity of global mild behavioural impairment symptoms [65].

Acquired physical health conditions such as hearing loss and head injuries have also been studied in relation to mild behavioural impairment symptoms in observational and case-control designs. Gosselin et al. (2022) found that poor hearing was associated with a greater severity of global mild behavioural impairment symptoms, as was the presence of specific mild behavioural impairment domains such as apathy and affective dysregulation [66]. Gosselin et al. (2023) also found that untreated hearing loss, particularly in individuals who did not use hearing aids, was linked to the presence of both global and domain-specific mild behavioural impairment symptoms such as social inappropriateness, affective dysregulation, and impulse dyscontrol [67]. Head injuries have been associated with mild behavioural impairment symptoms. Richey et al. (2023) found that a history of multiple head injuries was related to greater severity of mild behavioural impairment symptoms, particularly in domains such as affective dysregulation and impulse control [68].

Chronic conditions, particularly diabetes mellitus, have also been linked to mild behavioural impairment. Soo et al. (2021) discovered that the prevalence of diabetes mellitus was associated with the presence of global mild behavioural impairment symptoms, as well as specific domains such as decreased motivation, emotional dysregulation, impulse control, and abnormal thoughts [69]. Their findings also indicated that a higher prevalence of diabetes mellitus was associated with a greater severity of global mild behavioural impairment symptoms, particularly when mild cognitive impairment was present [69].

Psychosocial correlates of mild behavioural impairment

Compared with the neurocognitive and physical correlates of mild behavioural impairment, fewer studies have focused on psychosocial factors. These factors include depressive symptoms, loneliness, quality of life, caregiver burden, and the efficacy of educational interventions among individuals with mild behavioural impairment. Most of the evidence comes from cross-sectional studies ($n = 4$) and one randomised controlled trial.

The relationship between depressive symptoms and the severity of global mild behavioural impairment has been demonstrated in studies by Mallo et al. (2018) and Tsai et al. (2023) [17, 56]. Tsai et al. (2023) also found that the presence of mild behavioural impairment in specific domains such as decreased motivation and emotional dysregulation is associated with a decline in the quality of life [56]. Psychosocial correlates of mild behavioural impairment have also been examined in relation to loneliness. Matsuoka et al. (2024) found that higher levels of loneliness are associated with greater severity of both global and domain-specific mild behavioural impairment symptoms, including decreased motivation, affective dysregulation, and abnormal thoughts and perceptions [39].

One study explored the psychosocial impact of mild behavioural impairment symptoms on caregivers. Sheikh et al. (2018) found that both the presence and severity of global mild behavioural impairment symptoms were related to higher levels of caregiver burden, suggesting that mild behavioural impairment not only affects individuals directly, but also has significant implications for those who care for them [70].

In terms of interventions, one single-blind randomised controlled trial focused on the positive impact of educational interventions on individuals with mild behavioural impairment. Lin et al. (2023) demonstrated that interventions that aimed to enhance coping mechanisms, stress adaptation, and knowledge among older adults with mild cognitive impairment led to improvements in cognitive function [34]. Lin et al. (2023) conducted a descriptive qualitative study that showed improvements in coping strategies for managing daily hassles and emotional responses among individuals with mild behavioural impairment who participated in an educational psychobehavioural program [34]. Because the primary goals of these interventions targeted psychological well-being and social functioning, they were categorized under psychosocial correlates, consistent with the established definitions of psychosocial interventions [71].

Discussion

Overview and trends in mild behavioural impairment research

This scoping review underscores the growing recognition of mild behavioural impairment as an early marker of neurobehavioural symptoms that precede the clinical stages of dementia. A review of 41 studies published up to May 2024 indicated a surge in mild behavioural impairment research, particularly from 2022 to 2024, highlighting its global importance in the context of aging and cognitive health. The diversity in study populations and methodologies, from small-scale studies to extensive surveys with over 10,000 participants, primarily utilising cross-sectional designs, underscores the multifaceted factors associated with mild behavioural impairment across the spectrum of neurocognitive, physical, and psychosocial domains.

Neurocognitive correlates

Most studies have primarily focused on the association between mild behavioural impairment and neurocognitive factors, including biomarkers, progression to dementia, structural brain network changes, and cognitive and functional decline. Importantly, our synthesis emphasised

the identification of specific neurobiological characteristics, rather than detection tools, that were associated with the presence or severity of mild behavioural impairment symptoms. For instance, studies examining genetic and fluid biomarkers, neuroimaging patterns, and brain atrophy were interpreted in terms of their correlation with behavioural symptomatology, rather than their standalone diagnostic value. Key findings linked genetic markers, such as β-amyloid, tau protein, and neurofilament light, to the presence of mild behavioural impairment [33, 42, 44, 50], particularly in domains such as affective dysregulation [37, 41]. Additionally, changes in brain structure and function, particularly in the frontoparietal control network and medial temporal lobe, were associated with specific domains in mild behavioural impairment symptoms such as impulse dyscontrol and decreased motivation [43, 49, 72]. Reduced functional connectivity in critical brain areas, including the medial prefrontal cortex and left anterior insula, was a significant correlate, underscoring the importance of neuroimaging and neurophysiological measures in identifying individuals at heightened risk of significant neurological changes [38]. While most studies focused on the relationship between biomarkers and the presence of mild behavioural impairment symptoms, a few explored its relationship with the severity of mild behavioural impairment severity such as altered plasma Aβ42/Aβ40 ratios [46, 48], increased β-amyloid burden, and reduced metabolic activity on 18 F-fluorodeoxyglucose PET scans [47]. Future studies focusing on the severity of global mild behavioural impairment symptoms and their specific domains could potentially deepen our understanding of the distinct characteristics and genetic markers associated with mild behavioural impairment, enabling more precise and personalized management strategies.

The link between mild behavioural impairment and cognitive decline, including the accelerated onset of dementia, highlights mild behavioural impairment as a critical early indicator of neurodegenerative potential [4, 14, 15, 20, 52–57, 59, 61, 62]. Additionally, the significant impact of mild behavioural impairment on daily living activities [17, 56] underscores the need for a comprehensive assessment and management approach that integrates both neurocognitive and physical dimensions. This relationship is particularly emphasised in sex-specific approaches, where addressing the differential impact of mild behavioural impairment symptoms on cognitive decline by stratifying individual characteristics is crucial [58]. Therefore, to effectively identify individuals at risk of cognitive and functional decline, it is important to stratify those with mild behavioural impairment based on specific underlying characteristics such as sociodemographic factors and underlying health conditions. This approach would significantly enhance the accuracy of at-risk group identification and allow for more targeted and effective interventions.

Despite significant advances in exploring the neurocognitive correlates of mild behavioural impairment, gaps remain in the understanding of the causal relationships between neurocognitive factors and mild behavioural impairment symptoms. Future studies should focus on clarifying these mechanisms to support the development of targeted interventions. Prospective longitudinal studies, including randomised controlled trials, are essential for monitoring biomarker changes over time and establishing solid evidence-based connections between cognitive decline and behavioural changes. These would offer a more dynamic perspective on the progression of mild behavioural impairment with respect to neurocognition.

Physical correlates

Studies have also revealed an association between mild behavioural impairment and various physical conditions, including geriatric syndromes such as frailty and reduced gait speed, acquired physical conditions such as hearing loss and head injuries, and chronic conditions such as diabetes mellitus. Notably, Fan et al. (2020) and Guan et al. (2022b) demonstrated that both the presence and severity of mild behavioural impairment significantly increase the risk of frailty [63, 64], a relationship that is particularly pronounced in males with higher levels of frailty [64]. This finding underscores the importance of sex-specific analyses in tailoring interventions to address the combined effects of frailty and mild behavioural impairment. The potential for mild behavioural impairment to precipitate a decline in physical function underscores the increased burden on affected individuals, highlighting the importance of early detection to reduce the risk of developing associated physical conditions. Moreover, the link between gait speed and the severity of mild behavioural impairment suggests that changes in physical abilities could serve as early indicators of the development of mild behavioural impairment [65], and advocates the use of non-invasive assessments such as gait analysis to prevent dementia risk. To enhance our understanding and improve the identification and management of at-risk groups, it is essential to conduct further studies that stratify individuals with mild behavioural impairment into three specific age groups. Such a stratification would allow researchers to differentiate between the characteristics of geriatric syndromes that may arise because of aging. By examining these distinct age groups, researchers could identify how mild behavioural impairment manifests differently across the lifespan, and whether its symptoms are predominantly influenced by aging or other factors. Such research would offer deeper insights into whether mild behavioural impairment serves primarily as a precursor to physical

decline, or if there is a bidirectional relationship where the progression of functional decline also exacerbates mild behavioural impairment symptoms. These findings are important for developing tailored intervention strategies that consider the specific needs of different age groups, thereby improving outcomes for individuals at various stages of life.

Additionally, acquired physical conditions, such as hearing loss and head injuries, have been identified as significant factors of mild behavioural impairment [66–68]. These findings highlight the importance of conducting in-depth research on how the type and severity of these conditions, as well as the subsequent treatment process, influence the development and progression of mild behavioural impairment. Understanding the specific impact of functional decline or external injuries on individuals with mild behavioural impairment is essential for designing effective interventions and management strategies. Such research could also inform healthcare practices by identifying key points of intervention that may prevent or mitigate the worsening of neuropsychiatric symptoms following physical injuries or conditions. Future studies should consider not only the severity of injuries, the treatment processes, such as medication regimens, and the level of pain experienced, but also how these factors interact with the progression of mild behavioural impairment. This nuanced understanding is essential for developing targeted interventions and improving outcomes for patients affected by both physical and neuropsychiatric conditions. Moreover, the relationship between mild behavioural impairment and chronic conditions such as diabetes mellitus highlights the impact of metabolic factors on the severity of mild behavioural impairment [69]. This association emphasises the need for specialised care approaches for individuals with diabetes who are at risk of developing mild behavioural impairment. These interventions include physical treatment, cognitive function monitoring, and dietary modifications aimed at mitigating the exacerbation of cognitive decline. In addition to these approaches, future studies should explore the relationship between mild behavioural impairment and the presence and severity of other chronic conditions. Identifying at-risk groups and developing tailored management strategies through prospective longitudinal studies could enhance treatment compliance and improve outcomes for individuals with both chronic conditions and mild behavioural impairment.

Psychosocial correlates

Compared with the neurocognitive and physical correlates of mild behavioural impairment, fewer studies have focused on its psychosocial dimensions. Lin et al. (2023) highlighted the effectiveness of empowerment-based educational psychobehavioural internventions in improving mental health and overall well-being in individuals with mild behavioural impairment [34]. These interventions are necessary for enhancing coping strategies and reducing mild behavioural impairment symptoms, thereby offering a promising approach for improving the quality of life of affected individuals. Additionally, caregiver burden has been explored as a significant factor associated with mild behavioural impairment. Sheikh et al. (2018) has demonstrated the substantial emotional and psychological challenges faced by those caring for individuals with mild behavioural impairment. This burden, which intensifies with the severity of mild behavioural impairment, underscores the urgent need for support systems designed to mitigate the comprehensive impact of mild behavioural impairment on families and caregivers [70]. It also highlights the ripple effects of mild behavioural impairment on social and familial dynamics, emphasising the necessity of comprehensively addressing these challenges.

Furthermore, an association between depressive symptoms and the severity of mild behavioural impairment has been demonstrated [17, 56]. This relationship indicates that managing depressive mood may be important for effectively addressing mild behavioural impairment. Tsai et al. (2023) further explored this relationship, revealing that interventions targeting the reduction of mild behavioural impairment symptoms in specific domains such as decreased motivation and emotional dysregulation could significantly enhance health-related quality of life [56]. This underscores the transformative potential of behavioural interventions in improving the well-being of individuals with mild behavioural impairment. Matsuoka et al. (2024) has demonstrated a significant relationship between loneliness and mild behavioural impairment [39]. This finding underscores the importance of considering loneliness as a psychosocial factor that can exacerbate symptoms of mild behavioural impairment. Addressing loneliness through social interventions could play a crucial role in mitigating the severity of mild behavioural impairment and improving the overall mental health and quality of life of affected individuals.

Nonetheless, research in this area is challenged by the heterogeneity of study populations and small sample sizes, which may limit the generalisability of the findings. This limitation highlights the need for more comprehensive and methodologically robust research to understand the psychosocial correlates of mild behavioural impairment. Addressing these gaps is essential for developing comprehensive support mechanisms and interventions tailored to the psychosocial needs of individuals with mild behavioural impairment and their caregivers. Such efforts can inform more nuanced policymaking and

intervention strategies across the fields of nursing, psychology, and clinical practice, ultimately enhancing the support provided to this at-risk population.

Limitations

While we aimed to provide broad coverage of the topic, our review was limited to studies published between January 2003 and May 2024, and does not capture research developments beyond this date. Restricting the search to English-language publications may have introduced language bias and excluded relevant studies published in other languages, thereby limiting the comprehensiveness of our synthesis. Additionally, there is potential for publication bias, as studies reporting statistically significant or positive outcomes are more likely to be published and identified through database research. The inclusion of diverse study designs introduced heterogeneity in methodologies, populations, and outcome measures, which may affect the comparability of findings. Furthermore, our reliance on each study's own definitions of cognitive stages, such as mild cognitive impairment and subjective cognitive decline, may have affected the comparability of findings and introduced heterogeneity in outcome interpretation. Additionally, the exclusion of participants with dementia may have limited the scope of the findings, particularly when stratified data were unavailable.

Variability of the use of validated mild behavioural impairment assessment tools further limited the consistency of reported associations. Most studies were cross-sectional in design, which hinders conclusions about causality and restricts interpretation to associations. Several studies also had small sample sizes or narrowly defined populations, which may have limited the generalisability of the findings.

As this was a scoping review, we did not conduct a formal assessment of methodological quality, in line with the JBI framework [21]. However, the lack of quality appraisal limits our ability to comment on the robustness or reliability of individual study findings. Lastly, while our review aimed to map the breadth of existing evidence, this broad scope may have resulted in the omission of specific nuances or in-depth analysis. Therefore, it is important to remain aware of these limitations when interpreting our findings and considering their implications for future research.

Conclusions

This scoping review highlights the growing global importance of mild behavioural impairment research in aging and cognitive health, stressing the need for early detection and targeted interventions. It finds consistent associations between mild behavioural impairment and neurocognitive markers such as genetic risks and brain changes, which could help identify at-risk groups. Physical health factors, including geriatric syndromes and chronic diseases, are also significant. Emerging research points to the impact of psychosocial interventions along with mental well-being and caregiver challenges. Future studies should focus on psychosocial aspects, they should use prospective designs to explore causal mechanisms, and they should incorporate a diverse demographic to develop inclusive and effective interventions.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-06469-5.

Supplementary Material 1.

Acknowledgements
The authors thank the Medical Research Librarian, Dami Jeong, at the University of Yonsei for their assistance.

Authors' contributions
BK: Conceptualisation, methodology, writing–review, supervision, and funding acquisition. SY: Investigation, Formal analysis, writing the original draft, writing–review and editing. IJ: Investigation, Formal analyses. DH: Investigation, Formal analysis. JK: Writing the original draft, writing–review and editing.

Funding
This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (RS-2020-NR049581), an NRF grant funded by the Korean government (Ministry of Science and ICT) (RS-2022-NR072230), and a 2023 faculty–student research grant from Yonsei University College of Nursing (No.6-2023-0045). Dahye Hong received a scholarship from the Brain Korea 21 FOUR Project funded by the NRF of Korea, Yonsei University College of Nursing.

Data availability
All data generated or analysed during this study are included in this article.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 9 January 2025 / Accepted: 10 September 2025
Published online: 21 October 2025

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