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Review

Exploring the conceptual framework and measurement model of intrinsic capacity defined by the World Health Organization: A scoping review

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ABSTRACT

WHO has defined intrinsic capacity (IC) as the composite of all physical and mental capacities of an individual covering five subdomains: cognition, locomotion, sensory, vitality, and psychological. Despite this well accepted definition, the conceptual and measurement model of IC remains unclear, which hampers a standardized operationalization of the construct. We performed a scoping review to give a comprehensive overview of the extent to which the current literature of IC addresses and assumes the conceptual framework and measurement model of IC as reflective or formative. For inclusion, we considered all types of articles that were published in peer-reviewed journals except for protocol articles. A systematic search of 6 databases from different disciplines led to the inclusion of 31 papers. We found inconsistency and gaps in the descriptions of IC. Most of the papers did not define the measurement model. In the conceptual background and validation articles, we identified descriptions of both reflective and formative measurement models while in empirical studies applying IC measurements the underlying assumptions remained mainly unclear. Defining a measurement model is not merely a theoretical matter but influences the operationalization and validation processes of the construct. This study raised questions about the most fundamental features of the IC construct and discusses whether IC should be considered as an underlying latent trait of all capacities (reflective construct) or an aggregate summary measure of the subdomain capacities (formative construct).

1. Introduction

During recent decades, research on aging has gradually shifted the focus away from considering older age merely as a life phase of progressive functional decline and diseases to exploring the potential of older adults maintaining their functioning, wellbeing and contribution to society (Johnson and Mutchler, 2014). In line with this, in 2015, the World Health Organization (WHO) published a new public health model for healthy aging, which is oriented to promote functional ability and positive health attributes rather than presence or absence of medical conditions and disabilities (World Health Organization, 2015). According to this model, functional ability is determined by the intrinsic capacity (IC) of the individual, relevant environmental factors, and the interplay between these two. IC is defined as *"the composite of all the physical and mental capacities that an individual can draw upon at any point in their life"*, and the construct rests on the rationale that the capacities tend to decline with age although the trajectories are heterogeneous. The primary goal in supporting functional ability and healthy aging is to monitor and intervene to optimize the trajectories of individuals' IC during the aging process. However, despite decreases in IC in older age, functional ability may be maintained longer with environmental support and compensation strategies (Araujo de Carvalho et al., 2017; World Health Organization, 2015).

Based on expert meetings, literature reviews and empirical pilot

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analyses, WHO suggested five subdomains covering IC, namely, locomotion, cognition, psychological, sensory and vitality (Cesari et al., 2018). While the other domains represent mainly function of one dimension of the body system, vitality was conceptualized as an overarching domain capturing the underlying biological reserves of other more overt functional capacities (World Health Organization, 2018). So far, the discussion about the implementation of IC in research and clinical work has focused mainly on the operational definition of the construct. Although several validated measurements already exist to assess the IC domains separately, there has been a call for summary information of IC to track comprehensively the state and changes of capacities with a single score. However, there is no consensus on standard operational approaches to quantify IC. Two recent review studies examining the operationalization of IC in research concluded that the IC domains, especially vitality, have been assessed with very heterogeneous indicators across studies, and the methods of computing the IC score based on the domains are diverse (George et al., 2021; Gonzalez-Bautista et al., 2020).

The lack of a standardized way to measure IC may stem from the conceptual obscurity surrounding the construct. Despite the definition of the five domains and proposed indicators capturing these, not much attention has been paid to the nature of the construct. In other words, it is not clear what the relationship is between the IC construct, subdomains, and observed indicators. Traditionally, two kinds of measurement models using multiple indicators have been applied when assessing latent constructs (i.e., variables that are not directly observable but are inferred using observable indicators): reflective and formative models (Fig. 1). A measurement development draws on the reflective measurement model, which assumes that the observed indicators are manifestations of the construct under study, and thus, the variation in the underlying latent construct causes the observed variation in the indicators (Jarvis et al., 2003). For example, changes in anxiety cause variation in the item responses of an anxiety scale and not the other way around. Thus, the target of intervention for decreasing anxiety would be anxiety and not the indicators used to measure it. Because the indicators reflect the same underlying construct, they are expected to correlate with each other and show high internal consistency (Fleuren et al., 2018). Other examples of reflective measurement models include the measurement of intelligence with specific intelligence tests such as verbal fluency, working memory, and abstract reasoning (Deary, 2012), and pain interference with items covering the perceived negative impact of pain on functioning (Amtmann et al., 2010).

However, for some constructs, the causality between the indicators and the latent construct flow in the opposite direction, when the measurement model is specified as formative. For example, an individual's quality of life (QoL) may be measured with very heterogeneous items or indicators, such as income, health, social contacts, and happiness. These indicators may not be manifestations of an underlying common QoL but rather are defining characteristics of it (Felix and Garcia-Vega, 2012). In causal terms, the chosen indicators result in an overarching QoL. In this case, the target of intervention for improving QoL lies more likely in the different indicators and not in the QoL. The indicators in the formative model can but are not required to inter-correlate. Therefore, traditional psychometric techniques based on classical test theory, such as factor analyses and Cronbach's alpha, are not applicable to formative models (Costa, 2015). Other examples of formative measurement models include the measurement of socioeconomic position on the basis of specific socioeconomic indicators like education, income and occupational class, and gender inequality assessed with Gender Inequality Index composed of indicators representing three different dimensions of reproductive health, empowerment and the labor market (United Nations Development Programme, 2010).

One fundamental question regarding the novel IC construct is whether the domains or observed indicators of IC are assumed to reflect or form IC. The specification of the measurement model is not only a theoretical matter but guides the operationalization and validation processes. Therefore, the distinction should be done first on a conceptual basis before applying any statistical procedures in the instrument development and validation (Jarvis et al., 2003). During the past couple of years, research on IC has expanded. A thorough understanding of the construct that research is aiming to capture will lay grounds for more uniform and empirically valid measures of IC.

1.1. Purpose of the study

While previous reviews on operationalization of IC have focused on identifying the different measurements and methods used for operationalizing the separate domains or summary measure of IC(George et al., 2021; Gonzalez-Bautista et al., 2020), the purpose of this scoping review is to explore the descriptions and assumptions of the conceptual nature and measurement model of IC as defined by the WHO. This can be done by exploring the conceptual descriptions and evaluating operational approaches and assumptions underlying these methodologies in

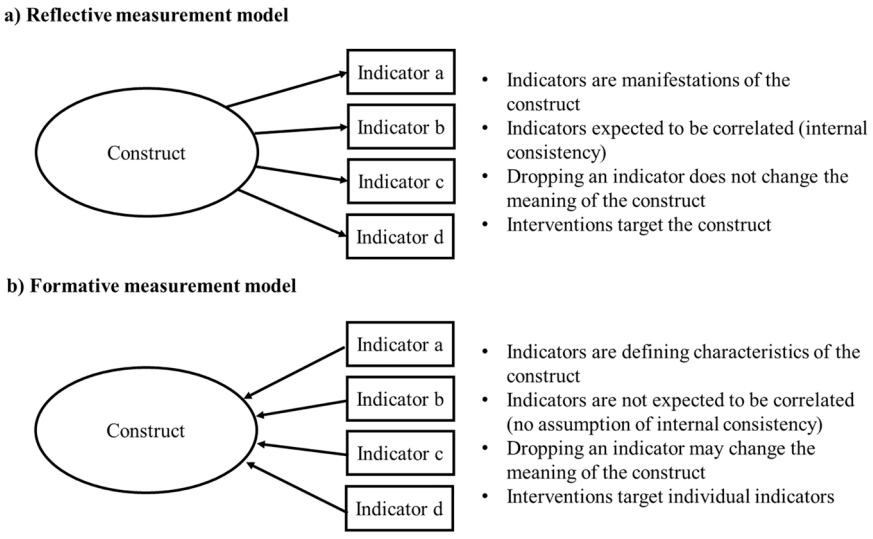

Fig. 1. Reflective and formative measurement models. Ovals represent unobserved latent variables, square boxes observed variables, and arrows the assumed direction of causality between these two.
Adopted and modified from Jarvis et al. (2003) and Fleuren et al. (2018).

the literature.

2. Methods

A scoping review method was adopted to explore the definitions and assumptions of the conceptual nature and measurement model of IC in the current literature. Scoping reviews are useful in mapping the existing literature within a specific area of research to give an overview of the topic and to identify gaps in knowledge while allowing variation in publication types selected for inclusion (Armstrong et al., 2011). We followed the 5-stage framework introduced by Arksey and O'Malley (2005) to conduct the scoping review, that is: 1) identifying the research question, 2) identifying relevant studies, 3) study selection, 4) charting the data, and 5) collating, summarizing, and reporting the results. The review was reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement (Tricco et al., 2018). The review protocol was not registered in advance.

2.1. Identifying the research question

The following research questions were identified to explore the descriptions and assumptions of the conceptual nature and measurement model of IC as defined by the WHO:

1. To what extent do researchers specify or describe the conceptual framework and measurement model of IC (i.e., how the indicators and the IC construct are related)? If so, do they specify or describe it as a reflective or formative model?
2. Do the operationalizations of IC follow the assumptions of the reflective or formative measurement model?

2.2. Identifying relevant studies

A literature search was performed in the bibliographic databases PubMed, Embase.com, Cinahl (via Ebsco), APA PsycInfo (via Ebsco), Web of Science Core Collection and Scopus from January 1st, 2015 to December 16th, 2021, in collaboration with a medical information specialist (LS). The IC concept as proposed by the WHO was introduced in 2015, which was the reason for the defined start of the time period. The following terms were used: 'intrinsic capacity' or 'intrinsic capacities'. Duplicate articles were excluded by a medical information specialist (LS) using Endnote X20.0.1 (Clarivate™), following the Amsterdam Efficient Deduplication (AED)-method (Otten et al., 2019) and the Bramer-method (Bramer et al., 2016). The full search strategies for all databases can be found in the Supplementary Information. Additionally, a hand search was performed in January 2022.

2.3. Study selection

Two reviewers (KK and NvS) independently screened all potentially relevant titles and abstracts for eligibility using Rayyan (Ouzzani et al., 2016). For inclusion in this scoping review, we considered all types of articles that were published in peer-reviewed journals except for protocol articles. In the included articles, conceptual basis of IC as proposed by the WHO or its operationalization had to be a central topic (Box 1). We excluded articles that used a fixed IC measurement, such as the Integrated Care for Older People (ICOPE) screening tool, of which development had been described elsewhere (World Health Organization, 2019). In addition, we excluded articles focusing on the broader concept of Healthy Aging proposed by the WHO. The publications had to be written in English.

After the first round of screening, reviewers met to resolve conflicts (n = 12) and discuss uncertainties (n = 50) related to the study selection. In total, 75 articles were included for full-text screening, which was conducted by one author (KK), and finally, 41 articles were initially identified from the full-text screening for data extraction and three through hand search. Finally, data were extracted from 44 articles (Fig. 2). The excluded publications after full-text screening with the reason for exclusion are presented in Supplementary Table 1.

2.4. Charting the data

The following study characteristics were extracted onto an Excel spreadsheet by one author (KK): author information and year of publication, type of the publication (e.g., original article, review, or perspective article), description of the publication, specification, or description of the conceptual and/or measurement model of IC (where appropriate), operationalization of IC (yes/no), computational approaches used in operationalizing IC (where appropriate).

The criteria for extracting information to distinguish assumptions of a reflective or a formative measurement model is presented in Table 1. The criteria for distinguishing the assumptions was adopted and shortened from the checklist introduced by Fleuren et al. (2018) and Jarvis et al. (2003). The original checklists were developed for researchers to identify the appropriate measurement model of constructs under study. The contents of the checklists were adjusted and shortened for the purposes of this review to identify potential assumptions and general understanding of the conceptual nature and measurement model of the IC construct in literature.

2.5. Collating, summarizing, and reporting the results

The first author (KK) organized the publications by their study objectives. A descriptive summary was created for each group of publications. In line with the recommendations on scoping reviews by Arksey and O'Malley (2005), we did not conduct a critical appraisal of individual studies since this review aimed to summarize existing literature and identify knowledge gaps.

3. Results

3.1. Study characteristics

Following the literature review, four categories of studies emerged: 1) background papers of the IC concept (n = 9), 2) empirical studies examining construct and structural validity of IC (n = 4), 3) empirical studies operationalizing and applying measurement of IC (n = 29), and 4) reviews summarizing original studies, in which IC was measured (n = 2). Table 2. represents characteristics of the included studies.

Box 1
Selection criteria.

Inclusion criteria The conceptual basis or operationalization of IC (WHO) is a central topic of the text	**Exclusion criteria**The conceptual basis or operationalization of IC (WHO) is not a central topic of the textNot written in EnglishWrong publication type (not published in peer-reviewed scientific journals) or protocol

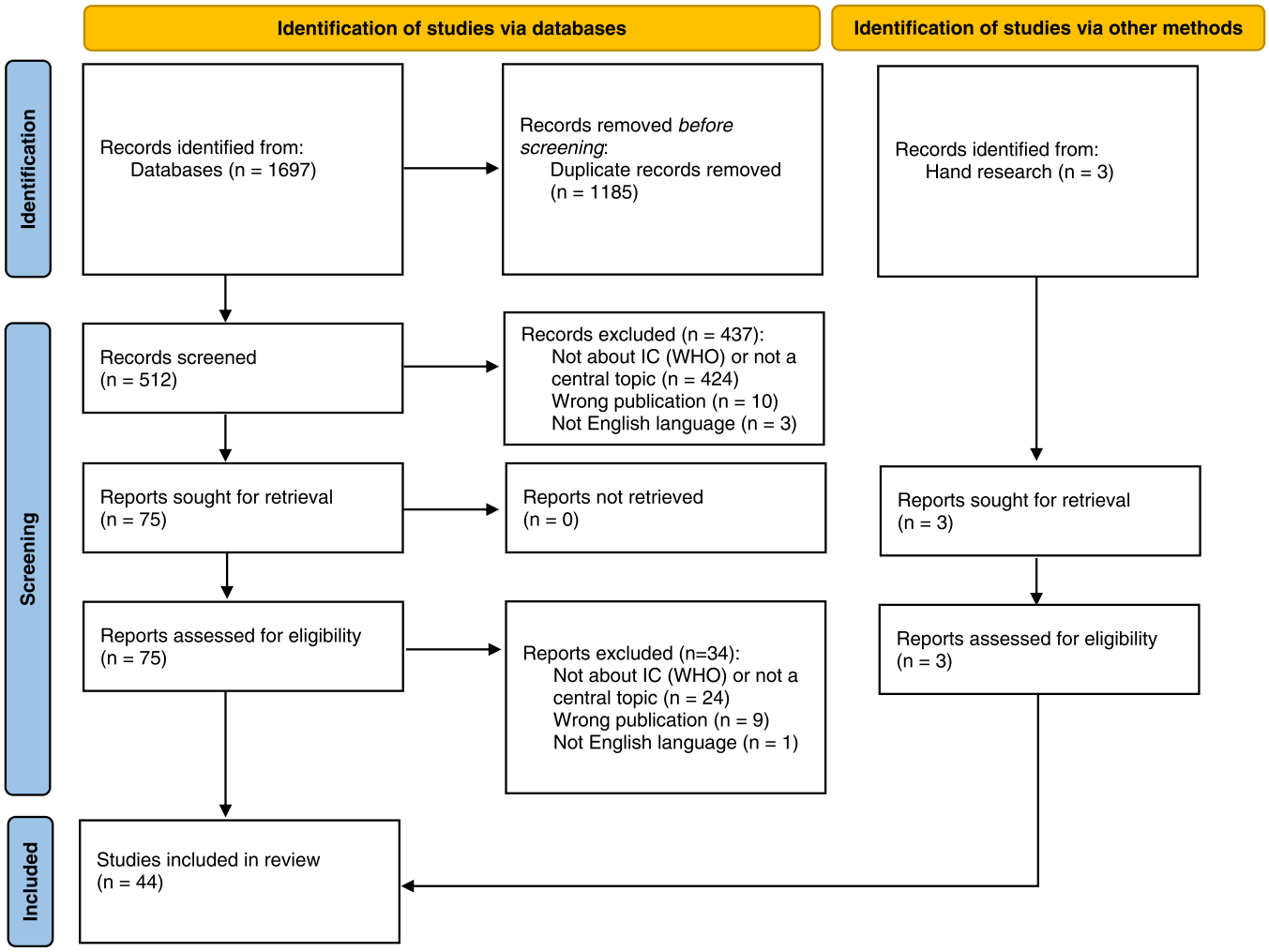

Fig. 2. Flow diagram of the study selection and inclusion process. *Note.* IC (WHO) = Intrinsic capacity defined by the WHO.

3.2. Background papers

The background papers of IC included two reviews related to the IC concept, two descriptive original papers and one editorial. Two of the articles provided a more detailed conceptual description of the construct (Cesari et al., 2018; Chhetri et al., 2021).

Cesari et al. (2018) described the development of the IC construct as part of the larger WHO's Healthy Aging model. Although the nature of the measurement model of IC was not explicitly specified, the presented conceptual figure in the study illustrates arrows flowing from the domains to the IC construct suggesting a formative model. The following legend was provided with this figure: *"The five domains (*i.e., *locomotion, sensory, cognition, psychological, vitality) constituting the intrinsic capacity construct"*.

In the other study, Chhetri et al. (2021) defined IC as "an aggregate summary of the physical and mental capacities of an individual" and specified the measurement model of IC explicitly as formative: *"IC is conceptualized as a composite measure where the component domains are treated as formative indicators (causal indicators)"*.

In addition, interacting and potential causal relationships between the domains or indicators of IC were described. For example, Cesari et al. (2018) describe how *"each domain closely interacts with the others"* and Nestola et al. (2020) give an example of how during COVID-19 social isolation, decreased possibilities of correcting vision and hearing loss may have affected other domains of IC. Moreover, Nestola et al. (2020) and Cesari (2022) highlight the hierarchical structure of IC in which the vitality domain represents a biological background, which becomes expressed in the more overt capacities.

3.3. Studies examining construct and structural validity of IC

Four articles examined the structure of IC aiming to empirically assess the validity of the IC construct. The first validation study was published by Beard et al. (2019), which has served as a basis for later studies validating and applying IC measures. Beard et al. (2019) describe and adopt a reflective measurement model (bi-factor analyses) in operationalizing the construct. The authors consider that the assessments of health and functioning in older age share common variance reflecting one underlying latent trait of general intrinsic capacity: "*Unlike approaches that use a composite total score which assumes that each indicator or measure contributes equally to the general factor (ie, intrinsic capacity), we used the bi-factor model scores that represents a pure measure of the underlying latent trait of interest, after controlling for all five specific subfactors*" (Beard et al., 2019). Yu et al. (2021) aimed to replicate previous work by Beard et al. (2019) and reported findings supporting the proposed structure of IC including one common and five specific factors.

In addition to the measurement model applied in the analyses with IC representing the underlying general capacity of the observed indicators, Beard et al., (2019, 2022) suggest a hierarchical structure of the IC domains. In this conceptualization, the vitality domain represents an underlying biological drivers influencing the expression of the other

Table 1
Criteria for distinguishing assumptions of reflective and formative measurement model, adopted and modified from Fleuren et al. (2018) and Jarvis et al. (2003).

Extracted information to assess measurement model	Interpretation	Example
1. Conceptualization of IC		
The observed indicators/ domains are assumed as a) defining characteristic of IC b) manifestations of IC c) not clear	"a" formative measurement model "b" reflective measurement model	a) IC is defined as an aggregate composite of an individual's capacities b) IC is defined as an underlying trait of an individual's capacities
It is assumed that a) changes in the observed indicators/domains cause changes in IC b) changes in IC cause changes in the observed indicators/ domains c) not clear	"a" formative measurement model "b" reflective measurement model	It is assumed that a) changes in the domains and/or indicators cause changes in IC b) IC is a general factor causing changes in the observed IC indicators across domains
2. Approaches used in operationalizing IC		
A change in one of the indicators/domains a) can, but is not expected to be associated with changes in the other indicators/domains b) is expected to be associated with changes in the other indicators/domains	"a" formative measurement model / not clear "b" reflective measurement model	a) Constructed index (e.g., an arithmetic mean or sum score) without expectation of covariation among indicators and without justification of the chosen approach does not provide clear information about the assumed measurement model b) Factor analyses underlie an assumption of covariation among the indicators and refers to a reflective model

more overt domains of capacities.

Gutiérrez-Robledo et al. (2021a) used different operationalization and validation methods compared to the three other studies of structural and construct validity. The scores of a short and a long version of IC were obtained using principal component analysis, which fundamentally rests on a reflective model although it is sometimes used in formative approaches (Mazziotta and Pareto, 2019). The authors also propose that central in the IC construct is the interaction between the elements: *"IC might be not only the sum of the domains, but also the "wellbeing" of the intercommunication between its functional domains."* (Gutiérrez-Robledo et al., 2021a).

3.4. Studies operationalizing and applying measurement of IC

The assumed measurement model was not specified or largely described in the studies operationalizing and applying IC in different settings (n = 29), but we explored whether it becomes apparent when looking at the methods of operationalizing IC. Table 3 presents the computational methods used in operationalizing IC and whether covariation among indicators was expected in the operationalization.

Most of the studies (n = 9) summed a total IC score of dichotomized indicators and two summed indicators divided in three categories. Seven studies build the IC score by first converting the domains into z-scores and then averaging the sum of the individual z-scores by the number of domains covered. Only one of these studies using a summation method expected covariation among the indicators and calculated Cronbach alpha to evaluate internal consistency of the created scale (Gutiérrez-Robledo et al., 2019), but generally, in these studies the assumed measurement model remained unclear and could not be interpreted. Finally, four studies applied factor analysis techniques in building the IC scores expecting covariation and high internal consistency among the indicators, which suggests reflective measurement model. In one study

Table 2
Characteristics of included studies.

Author (year)	Type of publication	Description of the study
1) Background papers		
Belloni and Cesari (2019)	Perspective article	Compares the IC and frailty concepts
Cesari et al. (2018)	Review	Describes the constituent elements of the construct of IC
Cesari et al. (2022)	Editorial	Describes the IC construct
Chhetri et al. (2021)	Original paper (descriptive article)	Describes the relationship between IC and physical resilience
Guaraldi & Milic (2019)	Review	Describes and the concepts of frailty and IC in aging and HIV infection
Nestola et al. (2020)	Original paper (descriptive article)	Describes how COVID-19 has potentially affected the persons' IC
Rivero-Segura et al. (2020)	Review	Describes the areas of opportunity and gaps of knowledge that must be addressed to integrate biomedical findings into clinically useful tools, such as IC, and interventions
Woo (2019)	Review	Compares the concepts of successful aging, frailty, intrinsic capacity, and resilience
Zhou and Ma (2022)	Opinion	Reviews the recent advances in IC research with older adults
2) Construct and structural validity of IC		
Beard et al. (2019)	Original research	Studies the factor structure of the total IC score using an English cohort of older adults aged ≥ 50 years
Beard et al. (2022)	Original research	Studies the structure of IC score using a Chinese cohort of older adults aged ≥ 49 years
Gutiérrez-Robledo et al. (2021a)	Original research	Studies the structure of IC, compares a short and a long version of an IC index and test their cross-sectional association with relevant health outcomes in a cohort of Mexican older adults aged ≥ 50 years
Yu et al. (2021)	Original research	Studies the structure and predictive ability of IC in a cohort of Chinese older adults aged ≥ 65 years
3) Application of IC		
Angioni et al. (2021)	Perspective article	Describes application of IC assessment by a mobile geriatric team during the COVID-19 pandemic
Arokiasamy et al. (2021)	Original research	Studies the association of handgrip strength separately with the five domains of IC among older adults aged ≥ 50 years in six middle-income countries
Charles et al. (2020)	Original research	Studies the predictive value of the domains of IC proposed by the WHO on the 3-year adverse health outcomes using a Belgian cohort of nursing home residents
Chew et al. (2021)	Original research	Studies the relationship between frailty and IC among community-dwelling older adults aged ≥ 50 years
Giudici et al. (2019)	Original research	Studies relationship of low-grade inflammation (LGI) and hyperhomocysteinemia (HHcy) with variation in four IC domains and in a combined IC z-score over a 5-year follow-up in French older adults aged ≥ 70 years
Giudici et al. (2020)	Original research	Studies the effect of omega-3 (ω-3) polyunsaturated fatty acid supplementation and a multidomain intervention (MI) on levels of IC among French community-dwelling older adults aged ≥ 70 years
González-Bautista et al. (2021a)	Original research	Studies the frequency of conditions associated with declines in intrinsic capacity according to an adaptation of

(*continued on next page*)

Table 2 (*continued*)

Author (year)	Type of publication	Description of the study
		the screening tool ICOPE Step 1 among French older adults aged ≥ 70 years
González-Bautista et al. (2021b)	Original research	Studies whether the ICOPE Step 1 screening tool is able to identify people at risk of developing frailty and disability in basic and instrumental activities of daily living among community-dwelling older adults aged 70–89 years in France
Gutiérrez-Robledo et al. (2019)	Original research	Studies the association of allostatic load with IC among community-dwelling Costa Rican older adults aged ≥ 60 years
Gutiérrez-Robledo (2021b)	Original research	Studies the levels of IC and factors related to its decline in Mexican older adults aged ≥ 50 years
Huang et al. (2021a)	Original research	Studies the longitudinal association between social frailty and IC using a three-year cohort of community-dwelling older adults aged ≥ 60 years in Japan
Huang et al. (2021b)	Original research	Studies the prospective associations between dietary patterns and IC trajectories over a 3-year period in community-dwelling older adults aged ≥ 60 years in Japan
Huang et al. (2021c)	Original research	Studies the effects of three types of exercise training on IC in older adults with subjective memory concerns (RCT) among community-dwelling Japanese older adults aged 65–85 years with subjective memory concerns
Lee et al. (2021)	Original research	Studies the association of IC with life-space mobility and whether age and gender modify this relationship among community-dwelling older adults in Singapore
Liu et al. (2021)	Original research	Studies the predictive value ICOPE screening tool on the incidence of functional decline and falls and compares its value with frailty among residents in Chinese care retirement community
Locquet et al. (2022)	Original research	Studies the ability of the IC construct to predict death and whether deteriorations in IC, measured over 1 and 2 years, are predictive of death using a cohort of Belgian older adults
Lu et al. (2021)	Original research	Studies how changes of IC and neighborhood physical environment impact FA (functional ability) trajectories of older adults aged ≥ 65 years in Hong Kong
Ma et al. (2020)	Original research	Studies the clinical utility of the WHO ICOPE screening tool in a Chinese population aged ≥ 50
Ma et al. (2021a)	Original research	Studies the association between inflammatory cytokines and IC in older adults aged 60–99 years
Ma et al. (2021b)	Original research	Studies the prevalence and factors associated with IC decline and examines associations between IC and adverse outcomes among Chinese older adults aged 60–98 years
Ma et al. (2021c)	Original research	Studies the association between plasma N-terminal pro-B-type natriuretic peptideand IC in a Chinese older population aged 60–97 years
Prince et al. (2021)	Original research	Studies the prevalence of decline in IC and its association with incident dependence and mortality among older adults ≥ 65 years in Latin America, India, and China
Ramírez-Vélez et al. (2019)	Original research	Studies the odds of adverse events for each of the IC domains for individuals with handgrip strength greater than the muscle weakness cut-off points, as compared with their weaker counterparts using a cohort of Columbian older adults aged ≥ 60 years
Sánchez-Sánchez et al. (2021)	Original research	Studies the associations of IC and its individual domains with mortality, hospitalization, pneumonia onset, and functional status decline in a population of nursing home residents in France
Stolz et al. (2022)	Original research	Studies changes in IC longitudinally and investigates whether repeatedly measured IC predicts 3 negative health outcomes (ADL disability, nursing home stay, and mortality) among community-dwelling older adults aged ≥ 70 years in the US
Yu et al. (2021)	Original research	Studies the predictive value of IC on one-year incident adverse outcomes among Chinese community-dwelling older adults aged ≥ 60 years
Yu et al. (2022)	Original research	Studies associations of IC, its five domains, and different combinations of domains with incident frailty among community-dwelling Chinese older adults aged ≥ 65 years
Zeng et al. (2021)	Original research	Studies the impact of IC domains on the adverse health outcomes including new activities of daily living (ADL) dependency, new instrumental activities of daily living (IADL) dependency, and mortality over a 1-year follow-up among hospitalized Chinese older adults aged ≥ 60 years
Zhao et al. (2021)	Original research	Studies the IC status and whether impairment in IC predicts subsequent 1-year activities of daily living (ADL) disability better than a disease-based approach using a cohort of Chinese adults aged ≥ 65 years
4) Reviews of the measurements of IC		
George et al. (2021)	Review	Review of the measurement tools, methods used for computation of a composite IC index and factors associated with IC among older adults
González-Bautista et al. (2020)	Review	Reviews how intrinsic capacity has been assessed in older adults and if these measurements have been validated

Note. ICOPE = Integrated care for older people.

(Stolz et al., 2022), a variable (hearing impairment) was excluded from the IC score due to low correlation with other IC variables.

3.5. Reviews of the IC measurements

Two reviews summarized characteristics of how IC has been measured among older adults (George et al., 2021; Gonzalez-Bautista et al., 2020). Both reviews revealed the heterogeneous approaches and highlighted a need for a standard IC score and validation of the concept, especially regarding the vitality domain. The suggested methods to improve validity and reliability of the IC composite score included using measurement tools that are validated and less prone to bias, using appropriate weightage for different IC domains, using a concrete operational definition of vitality, and expressing IC with a continuous score. Based on the reviews, the suggested measurement model that serves as a

Table 3
Computational approaches in operationalizing the IC construct.

Method	Covariation among indicators*	Number of articles	Studies
Domains operationalized and analyzed separately	Not expected	7	Angioni et al. (2021), Arokiasamy et al. (2021), Charles et al. (2020), González-Bautista et al. (2021a),Prince et al. (2021), Ramírez-Vélez (2019),Yu et al. (2021)
A composite IC score defined as the sum of each domain's z-scores divided by the number of domains covered	Not expected	7	Giudici et al., (2019, 2020),Huang et al. (2021a),Huang et al. (2021b),Huang et al. (2021c), Locquet et al. (2022),Sánchez-Sánchez et al. (2021)
A summed total IC score of dichotomized indicators	Not expected	9	Chew et al. (2021), González-Bautista et al. (2021b), Gutiérrez-Robledo et al. (2021b),Liu et al. (2021), Ma et al. (2020),Ma et al. (2021a),Ma et al. (2021c),Zeng et al. (2021),Zhao et al. (2021)
A summed total IC score of indicators divided in 3 categories	Expected (n = 1), Not expected (n = 1)	2	Gutiérrez-Robledo et al. (2019),Ma et al. (2021b)
Factor analyses used to derive a composite IC score	Expected	4	Lu et al. (2021),Lee et al. (2021), Stolz et al. (2022),Yu et al. (2022)

Note. *Based on the operationalization method used in the study.

fundamental basis for the summary score construction remained unclear and could not be interpreted with certainty.

3.6. Summary of the conceptual and measurement model of IC in the current literature

Only in one study, the measurement model was explicitly specified as formative, although it could be inferred from many background and validation articles. In empirical studies applying IC measurements, the underlying measurement model remained mainly unclear.

Despite using the same verbal definition of IC, we found in the current literature inconsistencies in the descriptions of the conceptual and measurement models. While the background articles pointed more towards a formative model, in which the IC construct "emerges" from its five domains, the construct validation articles described IC as a common underlying construct reflected by its indicators across domains and used operationalization methods aligning this conceptualization. In addition, Beard et al., (2019, 2022) proposed a hierarchical conceptual model comprising of two levels (vitality and other more overt capacities).

In addition to formative and reflective conceptualizations of IC, we could identify descriptions of IC with interrelating components. According to this view, IC may be interpreted as a system, which depends on the quantity and quality of the dynamical interrelations between its elements (capacities). This network could be considered to represent the construct without a need to call on any latent variables (Guyon et al., 2017).

4. Discussion

4.1. Main findings

This study raised question about most fundamental features of the IC construct defined by WHO: *what* is the conceptual nature and measurement model of the construct? To answer this, we explored with a wide scope the emerging field of IC. Despite the uniform verbal definition and the structure of five subdomains presented in the studies, the results of this review showed that there are still inconsistencies and gaps in the general understanding of the construct. This hinders possibilities to reach a standardized way to operationalize IC and to validate the developed measurement tools.

Most of the studies which conceptualized or operationalized IC did not make explicit definitions of the measurement model or provide any rationale for chosen operational approaches. It is possible that the form of the measurement model is considered as self-evident (e.g., a formative index), or the lack of definition indicates unawareness of the conceptual distinctions between different measurement models when developing summary scores. This may be explained by the fact that, historically, in medical research there has been less attention for measurement theories, even though complex constructs are being measured. However, we identified features of both reflective and formative measurement models, both of which could be theoretically applied to the concept. On the one hand, the observed variables in the IC scales may be considered to reflect function of the body as a whole. On the other hand, different domains of capacities can be interpreted to be separate but possibly interacting entities in the system, which form an aggregated construct of physical and mental capacities. The distinction between measurement models is not always a clear cut (de Vet, 2011), which highlights the importance of specifying the underlying conceptual model when developing new constructs and before applying data driven approaches. In the following sections, some considerations regarding the reflective and formative models will be discussed.

4.2. Considerations regarding the reflective model

In the reflective scenario, the variables are expected to be interrelated as they manifest the same underlying latent trait, which exists independent of its indicators. Consequently, the indicators are interchangeable and the suitability of the variables in the IC scales should be partly based on the common variance between them, which may lead to abandonment of some conceptual meaningful indicators due to low internal consistency. This was observed in one included study in this review applying factor analysis in the scale construction (Stolz et al., 2022). Although two studies reported satisfactory estimates for internal consistency with a very wide array of indicators across the IC domains (Beard et al., 2019, 2022), more evidence would be needed to establish one underlying latent trait of general IC if the construct should be considered as reflective. However, high covariation between variables and estimates of internal consistency do not have any value in "proving" the existence of the underlying construct or measurement reliability if it is not reflective by its nature (Gruijters and Fleuren, 2018).

The declining capacities is the underlying rationale of the IC concept (Belloni and Cesari, 2019), which may give a reason to expect that the variables vary together because they are impacted by aging. The biological mechanisms, such as the cellular and molecular hallmarks of aging (López-Otín et al., 2013), could therefore provide a physical basis in the body function for the psychometric general capacity factor. Subsequently, when translating the idea of general capacity into practice, these biological aging mechanisms could be targeted by interventions to enhance IC. This, however, overlaps with the conceptualization of the vitality domain. In addition, one may wonder whether all the individual capacities can be expected to be related and manifest similar aspects of aging. This dissonance concerns perhaps mostly the psychological domain, which levels and trajectories may be very different from physiological and cognitive ones. Research suggests that resources related to sense of control and ability to mentally adapt to adversities may be preserved or even improved through growth, experiences and learning during aging (Charles and Carstensen, 2010; Wister and Cosco, 2021), and these capacities may be essential in compensating physiological losses.

In addition, the reflective model relies on the assumption that there is no direct causal relationships between the observed indicators but the changes and covariation between the indicators are caused by the common underlying latent trait (Schmittmann et al., 2013), which may not either fit well to the descriptions of IC. As described by Nestola et al. (2020), declines in one domain of functioning may lead to declines in other domain of functioning, and changes in vitality representing the shared biological background would cause changes in all the other domains (Beard et al., 2022).

4.3. Considerations regarding the formative model

The formative approach is seldom recognized in health and medical research although many measurements in this field could be conceptualized as composite indexes (Avila et al., 2015; Fleuren et al., 2018). In contrast to the reflective model, one theoretical aspect of applying the formative model is that the IC construct cannot theoretically be considered to remain the same if the used indicators vary considerably. In other words, using very heterogeneous variables or omitting a key component of IC, which was observed in many articles operationalizing it, alters the construct although the instruments carry the same name (Jarvis et al., 2003).

Defining the IC construct as a formative construct implies that interventions aiming to improve IC in different populations should target its different aspects, i.e., domains (Fleuren et al., 2018). Thus, the formative measurement model aligns with the multicomponent programs suggested by the WHO to enhance IC first at different domains of functioning, which would result in increased overall performance (Araujo de Carvalho et al., 2017; World Health Organization, 2019).

An important question is whether and when it is useful to construct and use a composite measure of IC. Combining different indicators leads to loss of information on the underlying capacities. Some studies included in this review operationalized and applied IC domains separately, which may have more clinical importance when planning care. In addition, it allows to explore the main drivers and patterns behind the performance as well as the relationships between the components as a system (Borsboom and Cramer, 2013; Fleuren et al., 2018), which was an aspect that arose in many of the included articles. Exploring relationships between IC components over time may reveal important dynamics of aging, which may help to develop policies and multicomponent interventions. However, sometimes it is more useful to summarize and monitor an individual's overall performance, for example, to identify trends (OECD, 2008).

4.4. Improving understanding and measurement of IC

To identify which measurement model suits better to the IC construct, we applied the longer version of the checklist formulated by Fleuren et al. (2018) and Jarvis et al. (2003); Table 4.). These lists were originally developed for a "thought experiment" to distinct between reflective and formative models when operationalizing a new construct. Earlier in the current article, we applied parts of the list to detect assumptions of the nature of the IC construct from the literature. As the original lists were not primarily developed for reviewing the literature, we only selected those parts that were suitable for data extraction from published studies.

Based on the checklist answers, it may be more reasonable to assume that changes in specific indicators or domains result in changes in IC and not the other way around. Thus, we suggest that IC should be considered as a formative construct consisting of five domains. However, deriving the exact theoretical measurement model of the whole construct requires more precise definition whether the subdomains are either reflective or formative by their nature. Although the content of five IC domains is largely accepted, the consensual conceptual and operational definitions of these are still elaborating as, for example, for locomotion (Veronese et al., 2022).

Table 4
Application of Fleuren et al. (2018) and Jarvis et al. (2003) checklist to the intrinsic capacity (IC) construct.

Checklist item	Application to intrinsic capacity
1. Are the domains a) defining characteristics or b) manifestations of the IC construct? "a" indicates a formative and "b" a reflective measurement model.	The five domains were identified as defining characteristics of IC with their specific observed indicators (Cesari et al., 2018). The word "composite" also refers to that the indicators constitute the IC construct. Thus, these factors suggest formative model. However, Beard et al. (2019) suggest that observed indicators of IC across five domains have common variance and are possibly measuring one common underlying trait of IC while also manifesting their specific subdomain, which refers to a reflective construct.
2. Would changes in the indicators/ domains cause changes in the construct or the other way around? The former indicates formative and the latter reflective.	For IC, it does not seem logical that the IC construct would change independently of its domains or observed indicators. It would be more reasonable to expect that changes in specific indicators or domains result in changes in the IC construct. Therefore, a formative measurement model seems to be more suitable.
3. Should each indicator/domain have the similar content or share a common theme? "Yes" indicates reflective; "no" indicates formative.	The five domains of IC and their observed indicators are selected to cover different aspects of body functioning that have been identified as predictors of functional ability during aging. Although the IC score can be an indication of function of the body system, the included domains may not capture the same aspects of aging. For example, a person may maintain good psychological capacity despite biological aging and losses e.g., in locomotor and cognitive capacities. Thus, a formative model is more appropriate.
4. Would dropping one of the domains/ indicators alter the conceptual meaning of the construct? "Yes" indicates formative; "no" indicates reflective.	Although individuals possess functional capacities independent of the observed indicators or defined domains of IC, each of the domains covers a different aspect of the construct that has been specifically defined (Cesari et al., 2018). Abandoning or adding one domain would alter the conceptual model of the IC construct. E.g., adding a new dimension of capacities, such as capacity to speak or communicate, would change the structure, which refers to a formative model.
5. Should a change in one of the indicators/domains be associated with changes in the other indicators/ domains? "Yes" indicates reflective; "no" indicates formative.	The domains and their observed indicators are potentially interrelated (Cesari et al., 2018) and have a hierarchical structure of vitality conceptualized as an overarching domain underlying the other more overt capacities (Beard et al., 2019, 2022). However, changes in some domains/ observed indicators may but are not expected to be always associated with changes in other domains. Capacity in one domain may be maintained despite declines in other domains of capacities suggesting a formative model.
6. Are the domains/indicators expected to have the same antecedents and consequences? "Yes" indicates reflective; "no" indicates formative.	The IC model relies on the rationale of declining capacities due to aging (Belloni and Cesari, 2019).Beard et al. (2019) suggest that all the capacities decline due to biological aging, which would fit to the reflective model. However, some aspects of IC, e.g., psychological, may remain unaffected despite biological aging. The answer

(continued on next page)

Table 4 (*continued*)

Checklist item	Application to intrinsic capacity
	suggests again formative measurement model conceptualizing and operationalizing the IC construct.

According to Diamantopoulos (2001), after defining a theoretical framework, at least four issues are critical in formative composite score construction that are content specification, indicator specification, indicator collinearity, and external validity. As formative models are fundamentally based on multiple regression and indicators are each expected to explain a unique aspect (and not common variance) in the construct, multi-collinearity can be seen as a sign that there is conceptual redundancy (Cenfetelli and Bassellier, 2009). However, from a theoretical perspective, removal of a collinear indicator may alter the meaning of the construct and needs to be carefully considered (Diamantopoulos and Winklhofer, 2001).

The main challenge of the formative models is assessing structural validity, which is usually done by examining how well the indicators relate to external measures of the developed score. External validity is necessary because a standalone formative measurement model cannot be identified in statistical models without an outcome (Fleuren et al., 2018). One possibility would be to use a global variable that summarizes the essence of IC or variables that are theoretical outcomes of it (Diamantopoulos and Winklhofer, 2001; Fleuren et al., 2018) that could be, for example, measures of functional (dis)ability.

4.5. Strengths and limitations

This is the first review to give a detailed overview of specifications and descriptions of the conceptualization and measurement model of IC showing inconsistencies and gaps in the fundamental understanding of the construct. The current review provides conceptual clarity on IC and, therefore, is an important contribution to the rapidly growing field applying the construct. Knowing that the IC term has been used widely in research on aging, we only included studies, which focused on the IC construct as proposed by the WHO. This enabled to examine accurately the same concept ruling out the possibility that the found inconsistencies in the assumptions result from different definitions. It is, therefore, worth noting that our findings and conclusions may not apply to other definitions of IC, and a reflective measurement model may be more suitable if IC is defined as a unidimensional concept.

This study has also some limitations. Although we defined a priori criteria for data extraction and interpretation based on different aspects of measurement models, we may have made misinterpretations about the researchers' potential assumptions about the nature of the IC construct. However, we did not want to make interpretation about the authors' assumptions based on used terminology but based our findings on larger descriptions and used methods. When developing and validating measures consisting of multiple indicators, many researchers may not know the differences between different conceptual or measurement models, which have roots in the field of psychology. However, it is common to adapt psychometric methods, such as factor analyses, in developing and evaluating instruments.

Moreover, the scoping review method does not provide means to do the quality appraisal of the included publications (Arksey and O'Malley, 2005), although in our synthesis we aimed to put more weight on the background articles and studies aiming to validate the IC construct, which more likely handled the central topics of the current review than the studies applying IC. In addition, the method does not allow to provide synthesis of the evidence in favor of reflective or formative measurement model but rather the synthesis is a narrative account of descriptions and used approaches. In future studies, it may be useful to use data-driven approaches to compare IC measurements of which development has been based on different approaches, although that does not help to define the appropriate measurement model, which should base always on the conceptualization of the construct.

4.6. Conclusions

If anything, this study has demonstrated that more attention should be paid to the nature of measurement models of health constructs, such as IC. Despite its importance, the measurement model is often disregarded. The issues raised and discussed in this paper have important implications for the interpretation of the IC construct proposed by the WHO. However, the same approaches can be used in analyzing and rethinking other multi-item health measurements helping researchers to develop complex, multidimensional assessments of health. We hope to stimulate discussion on this perspective to reach a harmonized understanding of the IC construct and its measurement.

CRediT author contribution statement

K. Koivunen: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **L.A. Schaap:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **E.O. Hoogendijk:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **L.J. Schoonmade:** Data curation, Writing – original draft, Writing – review & editing. **M. Huisman:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **N.M. van Schoor:** Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

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Declarations of interest

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.arr.2022.101685.

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