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ORIGINAL RESEARCH

The Global Research Trends on Intrinsic Capacity of Older Adults: A Bibliometric and Visual Analysis of Papers Published During 2015–2023

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Objective: The concept of intrinsic capacity (IC) revolves around healthy aging and active aging. Since the Introduction of the concept by the World Health Organization in 2015, a series of studies have been conducted by scholars from multiple fields. However, no bibliometric analysis has systematically investigated this issue. We aim to identify the current landscape and frontier trends of scientific achievements on IC in older adults through bibliometric approaches.

Methods: Quantitative analysis of publications relating to IC in older adults from 2015 to 2023 was interpreted and graphed through the Web of Science Core Collection database on December 5, 2023. A variety of quantitative variables was analyzed, including publication and citation counts, H-index, and journal citation reports. Co-authorship, citation, co-citation, and co-occurrence analyses were performed for countries/regions, institutions, authors, and keywords using the VOSviewer and CiteSpace.

Results: A total of 952 original and review articles in English were identified. The European countries possessed an absolute advantage in this field. The most contributive institution was the University of São Paulo. The most productive author is Cesari Matteo from France, followed by Qaisar Rizwan from the United Arab Emirates. However, a relatively low level of research cooperation existed between institutions and authors. Important topics mainly include the connotations, theoretical framework models, evaluation, screening tools, and application scenarios of IC. Among the promising hotspots, "biological aging", "ICOPE", "Covid-19", "prevention", "inflammation", "caf22", "prevalence", and "randomized controlled trial" displayed relatively latest average appearing year.

Conclusion: Global trends indicate a growing scientific output on IC in older adults, and developed countries are leading the way. There is still room for improvement in research team collaboration. The focus gradually shifts from theoretical research to empirical research. It is recommended to pay attention to the latest hot spots, such as "biological aging", "ICOPE implementation", "post-COVID-19 syndrome", and "biomarkers".

Keywords: intrinsic capacity, old adults, bibliometrics, research frontier, visualization

Introduction

Toward the end of the century, the number of older people worldwide is expected to surpass 1.5 billion, keeping pace with the population aging worldwide.[1] Aging is connected with an increased risk of physical and cognitive deterioration, which can lead to disability and loss of independence. Meanwhile, individual disparities in cognitive and physical performance become increasingly apparent as the aging process intensifies and accelerates.[2] According to the World Health Organization (WHO), healthy aging is the process of establishing and maintaining functional capacity that allows for well-being in old age.[3] Centenarians as an excellent example of resilience for successful aging, contribute to our better understanding of the underlying mechanisms of healthy aging. They do not escape physiological decline or age-related diseases or syndromes (ie, frailty), but the rate of such processes is slow enough to be offset by their increased functional capacity to respond to minor stresses of daily life (ie, resilience).[4] The WHO advocated in its World Report on

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Ageing and Health to change the focus from "disease" to "capacity" in older adults.[3] A concept of intrinsic capacity (IC) was introduced in this report to capture the integrated functioning of older adults as a whole. IC is described as an individual's whole physical and mental capacities.[5] At the same time, it also inaugurated the prelude to the research on IC assessment and the development of interventions to improve IC.

Healthy aging depends heavily on maintaining optimal IC, which is of vital importance to maintaining function. In terms of IC, physical and mental capacity are combined to determine the functional capability, in conjunction with environmental factors and their interactions.[6] In contrast to measuring deficits, the IC concept measures the capacities of multiple human biological systems that are most relevant to healthy aging. To implement IC in a clinical context, the WHO proposed five key domains of IC (including locomotion, vitality, cognitive, psychological, and sensory) and an innovative approach, the Integrated Care for Older People (ICOPE), which focused on improving IC to achieve healthy.[7] Despite early studies supporting the validity of the WHO Healthy Ageing framework built around the concept of IC, there was variation in the measurement process or tools used for assessing IC domains and there was no clear criterion for quantifying (or scoring) IC as a global measure.[8] To guide primary care practitioners to implement active personalized interventions to improve IC and functional ability in older adults, some highly specialized recommendations were provided in the ICOPE guidelines and handbook of WHO (apps.who.int/iris/handle/10665/258981), including addressing mobility loss, hunger, maintaining eyesight and hearing, preventing cognitive decline and depression, managing age-related diseases and falls, and supporting caregivers.[9] These conceptual advances and accompanying transformative research paradigms offer great potential for scientists and scholars to understand the determinants of healthy aging and possible opportunities for innovative interventions.[10] Although difficult to implement initially, a new era in aging research is entering with a focus on healthy aging.

It has been demonstrated that the five domains of capacity can be aggregated into an overall construct of IC, which predicts functional outcomes regardless of chronological age or chronic diseases.[11,12] Furthermore, IC has been associated with polypharmacy,[13] poor/fair self-rated health,[14] frailty,[15] falls,[16] and long-term nursing home residency.[17] Thus, routine monitoring of IC during midlife may be useful in the identification of early functional decline, which may be amendable by intervention. There is also increasing evidence that IC decline is associated with mortality and other negative health outcomes in older adults, although the majority of these studies did not have long follow-up times.[16,18,19] In the Yale Precipitating Events Project Study, the joint models' results, adjusted for sociodemographics and chronic diseases, show that a 1-point lower IC (on a scale of 0–100) was associated with a 7% increase in the risk for activities of daily living (95% confidence interval [CI]: 1.06–1.07), a 6% increase in the risk for long-term nursing home stay (95% CI: 1.05–1.07), and a 5% increase in the risk of death (95% CI: 1.04–1.05).[19] In the initial research phase, relevant studies are mainly concerned with the concept, operationalization, and epidemiological data of IC.[5–7] In addition, the assessment of the state of physical activity or rehabilitation training in clinical settings, such as the different stages of the post-stroke, post-surgery, and cancer were also areas of greater concern.[20–22]

In recent years, in the context of healthy aging and the global COVID-19 pandemic, IC-related literature is increasing year by year.[23,24] There is also a growing body of research concentrating on the development of therapies and the incorporation of innovative concepts into clinical and regular care for older persons.[14,19,25,26] A variety of review articles covering various aspects of IC in older persons have been produced as a result of the considerable literature on this topic. For example, some studies focused on IC assessment or related factors,[8,27–29] especially regarding the assessment tools.[8,28,29] In parallel, the relationship between IC and health outcomes in older persons has been studied by some scholars.[2,30] This contributes to our understanding of the importance of the ICOPE integrated care framework in maintaining the long-term health and quality of life of older adults. So far, some literature reviews for a specific topic of IC are done based on monitors;[31] digital health;[32,33] trajectory,[34] and so on. In other studies, scholars have reviewed intervention aspects of this field,[35–37] and the biological roots of the loss of IC that examine the mitochondrial function with IC domains by distinct mechanisms.[38] In general, researchers are unable to interpret current statuses and trends from various qualitative and quantitative investigations from a single perspective. Given the background and circumstances described above, it is critical to perform a study to review prior research findings and to update developing trends and hotspots on IC in older persons. It may give insight into the present breadth of relevant research and assist researchers in developing a framework of current and upcoming research objectives. As a result, the current study seeks to provide

a comprehensive bibliometric analysis of IC older adults over the 8 years 2015–2023 and also provide scholars who have entered or are about to enter this field of study with insights on the current state, emerging trends, and future research hot spots in this field from a global viewpoint.

Methods

Strategies for Data Collection and Search

We used the Web of Science Core Collection (WOSCC) database as the main data source. WOSCC, the world's largest and most complete scientific database, may provide scholars with high-quality literature and a solid foundation for their research.[39] All searches were performed on a single day, December 5, 2023, to avoid biases introduced by daily database updating. This bibliometric study on IC of older adults sought to identify the scientific output and activity regarding function-centered approaches in response to intensive aging through bibliometric Methods. The retrieval strategy was presented as follows: TS = ("intrinsic capacit*" OR "physical capacit*" OR "mental capacit*") AND AB=(old* OR elder* OR age* OR senior OR geriatric* OR geronto*) AND Language (English). We only considered original articles and reviews, and the timeframe covered January 1, 2015, to October 31, 2023. The titles, keywords, author information, abstracts, and references of all papers retrieved from WOSCC were downloaded and saved in plain text (Figure 1).

Data Extraction and Data Cleaning

Because of the spelling variations in this topic, a country/institution/author/journal may be divided into many countries/institutions/authors/journals. As a result, data pre-processing is required for accurate analysis. We established a standard Endnote export format (for example, author names formatted as Last name, A.B). The data was then manually cleaned in Microsoft Excel 2019. Two researchers worked separately on data extraction, analysis, and book selection to assure trustworthiness. We extracted data on the number of publications, citation frequency, countries of origin, authors,

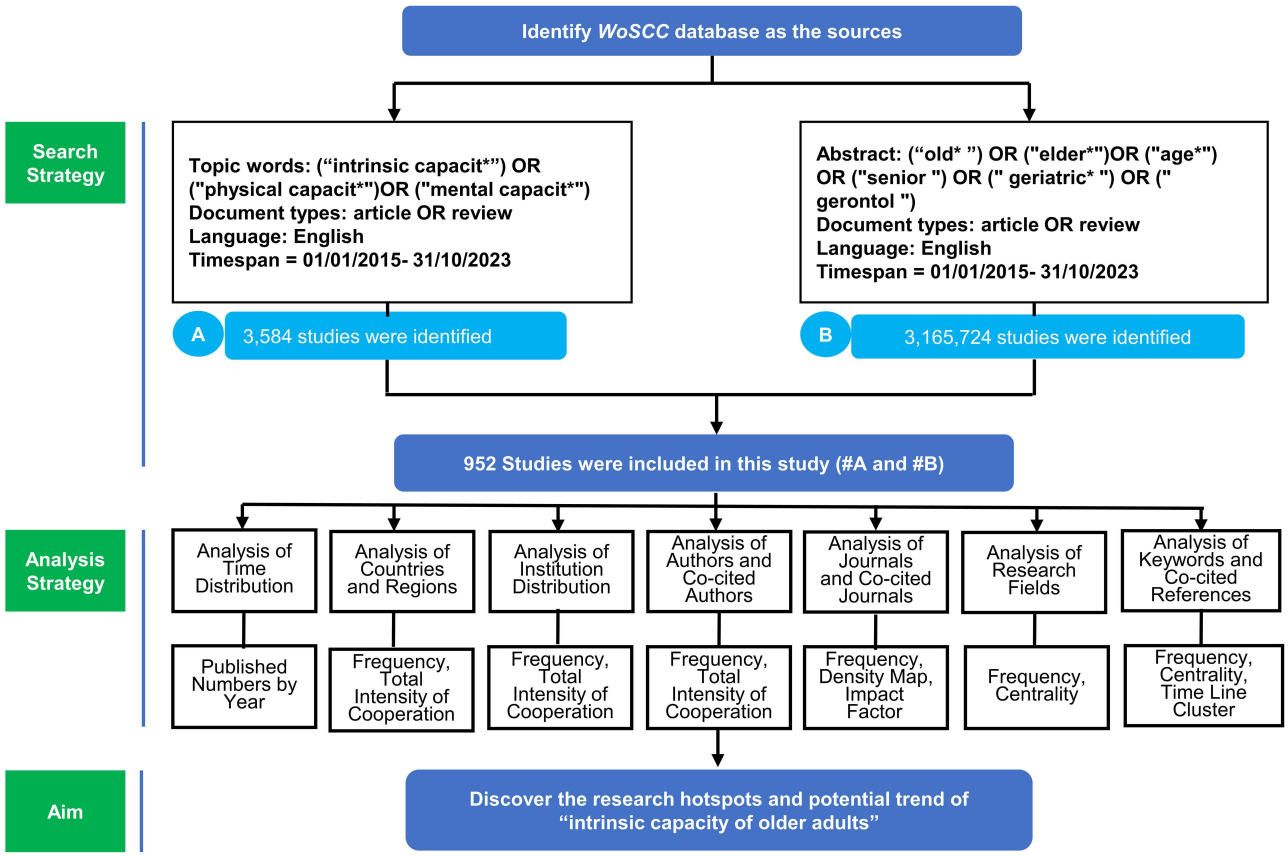

Figure 1 The flowchart of the research design.

journals, institutions, and funding sources from the selected papers. The journal impact factor (IF) and category of each journal were determined using the Journal Citation Reports (JCR) 2022 (available at: http://thomsonreuters.com/journal-citationreports/). The H-index was another key metric for judging scientific output and academic standing. It may also be used to assess the production and effect of a country, organization, or publication. After discrepancies between the researchers were discussed, data cleaning and analysis were done manually in Excel,[40] a process that involved finding the missing value, merging different spellings of the same country/institution (eg, Hong Kong, Macao, and Taiwan all belong to China; Harvard University and Harvard Univ are the same institutions). To prevent counting the same article twice, the nations and institutions were assessed following the first author's country and institution. Duplicate entries were eliminated, and publications unrelated to study themes were deleted, as a consequence of analyzing the titles and abstracts of the papers.

Bibliometric Analyzing

Microsoft Excel 2019 was used for descriptive statistical analysis of publications, which included the number of publications, the frequency of citations, the authors, journals, institutions, original nations, and the H-index. Scientific mapping tools were used for bibliometric analysis. We used two popular bibliometric analysis tools, CiteSpace6.2. R6 (Drexel University, Philadelphia, PA, USA) and VOSviewer1.6.18 (Leiden University, Leiden, The Netherlands), to develop the corresponding knowledge map by quantitatively analyzing the relevant literature, as in previous studies.[41–44] VOSviewer provides superior visuals for network and cluster research, but CiteSpace is superior for examining literature timelines.[45,46] As a result of their combined efforts, these two instruments can aid in the implementation of the visualization of intellectual structure as well as the process of development and evolution of this subject.[47]

VOSviewer was used for country/region citation analysis, institution citation analysis, journal co-citation analysis, keyword co-occurrence analysis, and reference co-citation analysis.[48] Meanwhile, VOSviewer was used to map and display a network of IC research hotspots (keywords). The nodes in the VOSviewer's network graphs represent various factors such as countries/regions, institutions, journals, authors, or keywords. Different colored nodes denote various taxonomies or periods of occurrence. Larger nodes have a greater betweenness centrality, which is derived by computing betweenness centrality for each parameter separately. Certain correlations among parameters are characterized by links between nodes. The total link strength (TLS) was utilized to objectively analyze the connections. The overall link strength of a node is the sum of its link strengths with all other nodes.[49]

CiteSpace was used for i) journal co-citation analysis, ii) journal dual-map overlay analysis, iii) institution co-authorship analysis, and iv) author co-authorship and co-citation analysis.[50] Each node in the visualization map reflects the sort of study being examined, and its size correlates to the number of occurrences or citations. The strength of collaborations, co-citations, or cooccurrences between nodes is represented by linkages between them. Nodes are colored based on their distribution time. In the figure, neighbor nodes form clusters based on relevant themes, and the flow of knowledge between clusters can be observed in the color shift between clusters. The VOSviewer and CiteSpace were used to evaluate all data from the WOSCC, and the findings are reported in the main text.

Results

The Publication and Citation Trends

From 2015–01-01 to 2023–10-31, the cumulative number of publications on IC of older adults was 952, which included 846 articles and 106 reviews. The average annual number of publications was calculated to be 105.78. As shown in Figure 2A, the number of global publications for IC research has gradually grown from 2015 to 2022; and 171 articles have been published in the related literature during the period of 2023–01-01 to 2023–10-31. An exponential function equation $y = 35.883e^{0.1913x}$ ($R^2 = 0.9559$, with x representing the year of publication and y the number of annual publications) for the trend in the number of publications was also established, with a good fit. It indicates that the research intensity of IC is increasing year by year, which is meaningful for in-depth study. A total of 12,596 citations have been recorded for all the published articles, with each paper receiving 13.2 citations on average.

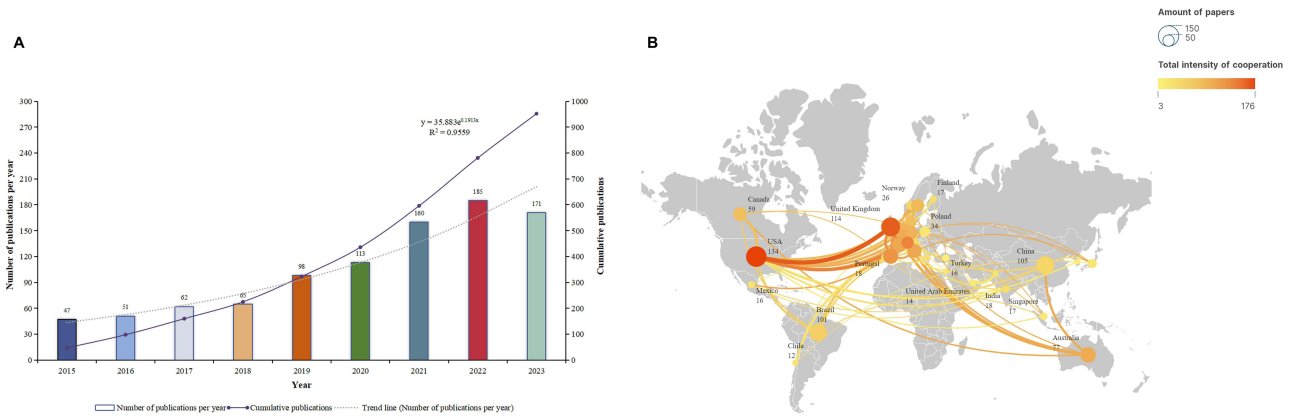

Figure 2 (**A**) Trend analysis of the number of publications by year (2015–2023). (**B**) Distribution and international cooperation of countries/regions that are involved in intrinsic capacity research. The color of the node reflects the intensity of the cooperation.

Countries / Region Analysis

A total of 78 countries/regions contributed to this topic research. The top 10 countries/regions were distributed across five continents (Europe, North America, Asia, South America, and Oceania), of which 5 were located in Europe (Table S1). With 134 papers published (14.07%), the United States ranked first, followed by the United Kingdom (114, 11.97%) and China (105, 11.03%). Concerning the country/region co-authorship analysis, the United States was at the center of research on IC, with close collaboration with the United Kingdom and Switzerland (Figure 2B). Countries/regions (31/78, 39.74%) with ≥ 10 publications (T = 3) were used to construct a Country/region co-authorship network based on the VOSviewer (Figure 2B). The network map had 76 nodes and 259 links. The number of articles issued is represented by the circles, the color of the circles symbolizes the total intensity of cooperation, and the lines between the circles show the cooperation between countries. Among the top three countries with the largest total intensity of cooperation were the United States (TLS = 176), the United Kingdom (TLS = 165), and Switzerland (TLS = 136).

Institution Distribution Analysis

In total, 1821 institutions published research on IC. The University of São Paulo contributed the most papers with 25, followed by Karolinska Institute and University of Copenhagen, both with 24 papers. Table S2 displays the top ten most influential institutions, as well as the number of articles produced by each. European institutions dominated this list (8/10). Figure 3A illustrates the institution's cooperative network map of research in IC. The number of articles published by the institution is represented by the size of a node. Only institutions with a minimum of 5 publications were included in the institution citation analysis. There were three institutions with the largest TLS: the University of Copenhagen (TLS = 56), King's College London (TLS = 37), and the World Health Organization (TLS = 37).

Authors and Co-Cited Authors Analysis

The top 10 authors with the highest number of publications are listed in Table S3. According to the WOSCC, the top 10 authors produced 109 publications, which accounted for 11.45% of all literature on this topic. Cesari Matteo from France was the author with the most publications 13, followed by Qaisar Rizwan from the United Arab Emirates with 12 papers. Figure 3B illustrates the map of author co-authorship networks. Each node in the network represents one author, and the size of the node indicates the number of articles published by the author. The connection between authors indicates the intensity of cooperation, and Different color regions represent different clustering information. Vellas Bruno was the author who had the highest link strengths with other authors (TLS = 47). Qaisar Rizwan and Karim Asima have the most intensive cooperation (TLS = 38).

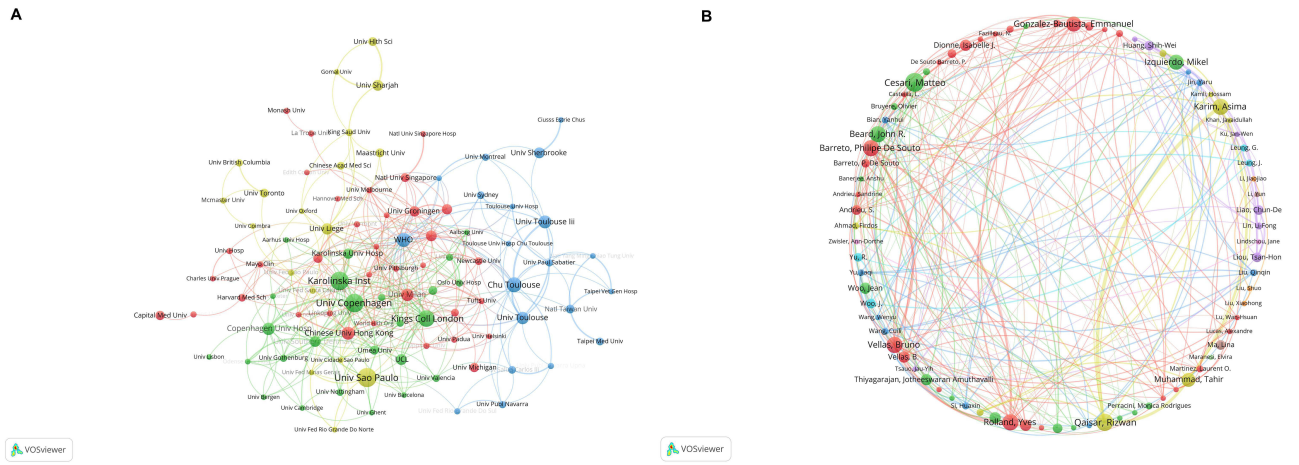

Figure 3 (**A**) The institution's cooperative network map of research in intrinsic capacity. (**B**) The author's cooperative network map of research in intrinsic capacity. Each node represents an institution/author, and node size indicates the number of publications. The connection between the nodes represents a citation relationship, and the thickness of the lines indicates citation strength.

Analysis of Journals and Co-Cited Journals

A total of 483 journals have been published in this field recently. Out of 952 papers published on IC, 183 were published by the top 10 active journals, accounting for 19.22% of the total (Table 1). Furthermore, we chose 3 minimum numbers of journal publications as a threshold value and subsequently got a density map (Figure 4A). According to Table 1, the International Journal of Environmental Research and Public Health published the most papers (33, 3.47%), followed by BMC Geriatrics (24, 2.52%), and the Journal Of Nutrition Health & Aging (23, 2.43%). Journal Of Nutrition Health & Aging has the highest impact factor of 5.8, followed by Journals Of Gerontology Series A-Biological Sciences And Medical (5.1) and International Journal Of Environmental Research And Public Health (4.6). Based on JCR 2022 standards, the top 10 most active journals were classified as Q1 in four, Q2 in five, and Q4 in one. Citations are one of the most important variables in determining the academic influence of a publication. Table 2 lists the top ten journals that have been cited more than 150 times. Journals Of Gerontology Series A-Biological Sciences And Medical has been the most frequently cited journal (474 times), followed by the Journal Of Nutrition Health & Aging (370 times), and International Journal Of Environmental Research And Public Health (245 times). Based on JCR 2022 standards, all of the top ten cited journals were in Q1/2.

Analysis of Research Fields

The 227 literature domain categories obtained from searching the WOSCC were visualized and analyzed by VOSviewer, and 952 articles of IC-related research were clustered into five major domains. As shown in Figure 4B, different colored

Table 1 Top 10 Journals in the Field of Intrinsic Capacity Research Ranked by Publication Number

Rank	Journal	Country	Count(%)	IF/JCR (2022/2021)	H-index
1	International Journal Of Environmental Research And Public Health	Switzerland	33 (3.47)	4.6/ Q1,Q2	78
2	BMC Geriatrics	England	24 (2.52)	4.1/ Q1,Q2	56
3	Journal Of Nutrition Health & Aging	France	23 (2.42)	5.8/ Q1	74
4	PLoS One	United States	20 (2.10)	3.7/Q2	268
5	Experimental Gerontology	England	17 (1.79)	3.9/Q2	124
6	Journals Of Gerontology Series A-Biological Sciences And Medical	United States	16 (1.68)	5.1/Q1	168
7	Aging Clinical And Experimental Research	Italy	14 (1.47)	4.0/Q2	63
8	BMJ Open	England	12 (1.26)	2.9/Q2	69
9	Frontiers in Medicine	Switzerland	12 (1.26)	3.9/Q2	39
10	Journal Of Aging And Physical Activity	United States	12 (1.26)	1.5/Q4	52

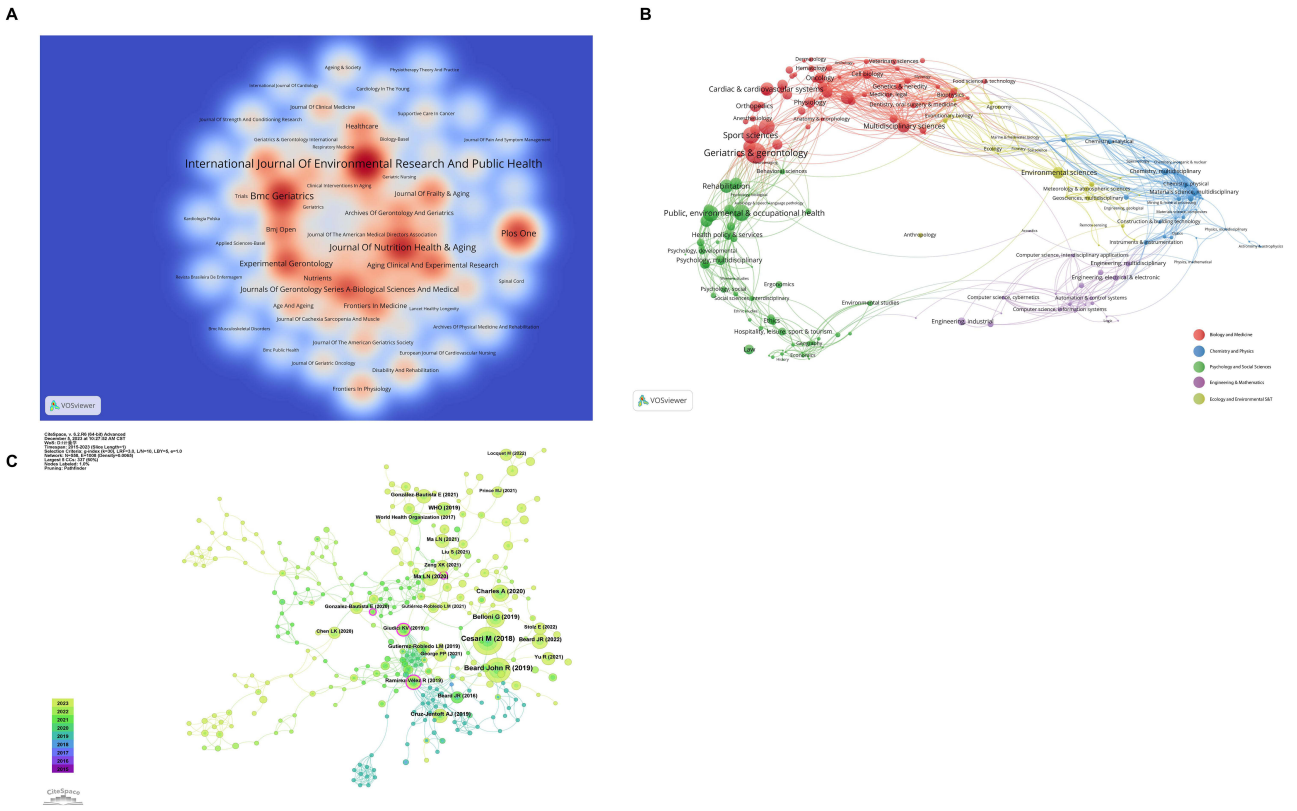

Figure 4 (**A**) Density map of journal publications of research in intrinsic capacity. The deeper the color of a node, the more numbers of journal publications. (**B**) Analysis of research areas in intrinsic capacity. Different colored spheres represent different converging fields. (**C**) Co-citation analysis of the literature of research in intrinsic capacity. The purple nodes represent the citation appearing earlier, whereas the green nodes reflect the recent citation.

orbs represent different domain clustering, IC-related studies were mainly concentrated in Biology and Medicine, with a relatively high percentage in the subfields Geriatrics & gerontology and Sport sciences. Secondly, it is concentrated in the field of Psychology and Social Sciences, in which the subfields of Public, environmental and occupational health account for a higher proportion.

Citation and Co-Citation of Literature

Table 3 lists the top 10 references with the highest citations, including 4 reviews and 6 articles. Among them, eight papers were completed as a result of collaboration between institutes. With 1164 citations, Beard et al published the most

Table 2 Top 10 Journals in the Field of Intrinsic Capacity Research Ranked by Numbers of Citation

Rank	Co-cited Journal	Country	Citation Count	IF/JCR(2022)	H-index
1	Journals Of Gerontology Series A-Biological Sciences And Medical	United States	474	5.1/Q1	168
2	Journal Of Nutrition Health & Aging	France	370	5.8/ Q1	74
3	International Journal Of Environmental Research And Public Health	Switzerland	245	4.6/ Q1,Q2	78
4	Experimental Gerontology	England	222	3.9/Q2	124
5	PLos One	United States	220	3.7/Q2	268
6	Frontiers in Medicine	Switzerland	195	3.9/Q2	39
7	BMC Geriatrics	England	184	4.1/ Q1,Q2	56
8	Scientific Reports	England	161	4.6/Q2	149
9	Journal Of Cachexia Sarcopenia And Muscle	Germany	152	8.9/Q1	48
10	British Journal Of Sports Medicine	England	152	18.4/Q1	141

Table 3 Top 10 Publications on Intrinsic Capacity Research with the Most Citations

Rank	Title	Main themes	Journal	First author	Year	Citation Count
1	The World report on ageing and health: a policy framework for healthy ageing	Redefinition of healthy ageing that centers on the notion of functional ability: the combination of the intrinsic capacity.	LANCET	Beard JR	2016	1164
2	Evidence for the Domains Supporting the Construct of Intrinsic Capacity	Five domains (ie, locomotion, vitality, cognition, psychological, sensory) are identified as pivotal for capturing the individual's intrinsic capacity.	Journals Of Gerontology Series A-Biological Sciences And Medical	Cesari M	2018	270
3	Patterns of Technology Use Among Older Adults With and Without Disabilities	Describe prevalence of technology use among adults ages 65 and older, particularly for those with disability and activity-limiting symptoms and impairments.	Gerontologist	Gell NM	2015	217
4	Skeletal muscle aging: influence of oxidative stress and physical exercise	Review of influence of oxidative stress and physical exercise in skeletal muscle aging.	Oncotarget	Gomes MJ	2017	169
5	Cognitive plasticity in older adults: effects of cognitive training and physical exercise	Results reviewed support the notion that cognitive plasticity for attentional control, as induced by cognitive training or physical activity and exercise, is preserved in late adulthood.	Neurosciences and Music V: Cognitive Stimulation and Rehabilitation	Bherer L	2015	156
6	Sedentary Behavior in the First Year After Stroke: A Longitudinal Cohort Study With Objective Measures	Quantified longitudinal changes in sedentary behavior after stroke to ascertain whether reducing sedentary behavior might be a new therapeutic target.	Archives of Physical Medicine and Rehabilitation	Tieges Z	2015	120
7	Organizing integrated health-care services to meet older people's needs	Integration at the level of clinical care is especially important: older people should undergo comprehensive assessments with the goal of optimizing functional ability and care plans should be shared among all providers.	Bulletin Of The World Health Organization	de Carvalho	2017	109
8	Copenhagen Consensus statement 2019: physical activity and ageing	To reach evidence-based consensus about physical activity and older adults.	British Journal of Sports Medicine	Bangsbo J	2019	99
9	Effects of elastic resistance exercise on body composition and physical capacity in older women with sarcopenic obesity: A CONSORT-compliant prospective randomized controlled trial	Identified the clinical efficacy of elastic resistance exercise training in patients with sarcopenic obesity.	Medicine	Liao CD	2017	93
10	Frailty and Intrinsic Capacity: Two Distinct but Related Constructs	Described the similarities and differences between the two constructs, highlighting how geriatric medicine contributed to their development.	Frontiers in medicine	Belloni G	2019	90

highly cited paper, which was a report on a redefinition of healthy aging that centers on the notion of functional ability.[3] The second most cited paper was a review that identified five domains (ie, locomotion, vitality, cognition, psychological, sensory) as pivotal for capturing the individual's intrinsic capacity.[5] The third most cited article described the prevalence of technology use among adults ages 65 and older, particularly for those with disability and activity-limiting symptoms and impairments.[51]

As shown in Figure 4C, the co-citation network map on IC from 2015–01-01 to 2023–10-31 was analyzed by CiteSpace with the parameters as time slices (2015–2023), years per slice (1), and selection criteria (k=30). The size of the superimposed circles, ie, the size of the corresponding circles on the chronological line is summed up and is proportional to the number of co-citations; purple represents relatively early citation, green represents late citation, and the superimposed color means that the article has been cited in all the corresponding years. The line between the circles represents the co-citation situation of the literature, and the nodes marked in rose red are the key nodes, with centrality greater than 0.1. The largest publication scale was held by "Cesari M (2018)"[5] (106 times) with active co-citations with "Beard John R. (2019)"[52] (84 times) and "Belloni G. (2019)"[15] (42 times). Table 4 shows the top ten references in terms of citations. The top five sources with the most citations came from Cesari M (106 citations),[5] Beard JR (84 citations),[52] Belloni G. (42 citations),[15] Charles A (41 citations),[16] and Cruz-Jentoft AJ (32 citations).[53]

Analysis of Co-Occurring Keywords

Keywords co-occurrence analysis is a useful technique for tracking scientific progress and identifying emerging trends and hot topics. The top 20 keywords from the WOSCC are ranked by frequency of occurrence in Table S4. In terms of co-occurrences, elderly and intrinsic capacity ranked as the most frequent keywords corresponded to the themes of this study, with 140 and 122 co-occurrences respectively. As for the other keywords, some were associated with the key elements of IC, for example, physical capacity, physical activity, and physical function. Some were linked to important considerations for public health, for example, healthy aging, quality of life, and covid-19. Others were related to adverse health outcomes of IC, such as frailty, sarcopenia, disability, and falls. To identify various research hotspots in this subject, we utilized the VOSviewer technique to map the primary keywords, selecting "co-occurrence" as the type of analysis and "all keywords" as the unit of analysis in this study. Furthermore, we used a threshold of 4 minimum numbers of co-occurrences of a keyword as a threshold value and obtained 135 keywords out of 2243 words to create the network visualization map (Figure 5A) and overlay visualization map (Figure 5B). The thickness of the connecting line in the visualization map of keywords indicates the degree of the co-occurrence link between keywords, demonstrating the association of their respective study foci. The size of the bubble denoted the frequency with which the keyword appeared.

As illustrated in Figure 5A, there were four major clusters of co-occurring keywords in IC research areas. The red clusters had the highest heat for "aging"; the yellow clusters had the highest heat for "healthy aging"; the green clusters had the highest heat for "covid-19" and "decision-making capacity"; and the blue clusters had the highest heat for "elderly". The colors in the network visualization map (Figure 5B) show different clusters created by keywords, while the colors in the overlay visualization map indicate the average appearance year (AAY) of the identified keywords. Before 2019, this field mainly focused on "functional status and rehabilitation in the clinical context". It is noteworthy that the keywords "biological aging", "ICOPE", "Covid-19", "prevention", "inflammation", "caf22", "prevalence", and "randomized controlled trial" displayed relatively recent AAYs, indicating that these keywords have increased in popularity in recent years and have the potential to become hotspots in the future. Figure 5C depicts a timeline view of the clustering plot, which facilitates the identification of developing research hotspots in IC.

Discussion

Essential Information

We retrieved 952 publications with 12,596 citations from the WOSCC's IC of older adults' literature from 2015–01-01 to 2023–10-31. We conducted a bibliometric analysis to acquire a better understanding of present research hotspots and potential trends, as well as to provide future researchers with valuable reference guides. The change in the number of scientific publications Results reflects the rate of development of a certain study area to some extent.[43] According to the

Table 4 Top 10 Co-Citation Analysis of Cited Reference on Intrinsic Capacity Research

Rank	Title	Main themes	Journal	First author	Year	Co-citation Count
1	Evidence for the Domains Supporting the Construct of Intrinsic Capacity	In order to facilitate the translation of the intrinsic capacity theoretical model into practice, it is important to identify the inner nature of its constituting constructs.	Journals Of Gerontology Series A-Biological Sciences And Medical	Cesari M	2018	106
2	The structure and predictive value of intrinsic capacity in a longitudinal study of ageing	To assess the validity of the WHO concept of intrinsic capacity in a longitudinal study of ageing.	BMJ OPEN	Beard JR	2019	84
3	Frailty and Intrinsic Capacity: Two Distinct but Related Constructs	The similarities and differences between frailty and intrinsic capacity, highlighting how geriatric medicine contributed to their development and will be crucial for their further integration in future healthcare models.	Frontiers in medicine	Belloni G	2019	42
4	Prediction of adverse outcomes in nursing home residents according to intrinsic capacity proposed by the World Health Organization	To evaluate the predictive value of the domains of intrinsic capacity proposed by WHO on the 3-year adverse health outcomes of nursing home residents.	Journals Of Gerontology Series A-Biological Sciences And Medical	Charles A	2020	41
5	Sarcopenia: revised European consensus on definition and diagnosis.	To update the original definition of sarcopenia in order to reflect scientific and clinical evidence that has built over the last decade.	Age and Ageing	Cruz-Jentoft AJ	2019	32
6	Integrated care for older people screening tool for measuring intrinsic capacity: preliminary findings from ICOPE pilot in China	To determine the clinical utility of the WHO ICOPE screening tool in a Chinese population.	Frontiers in medicine	Ma LN	2020	31
7	Intrinsic Capacity: Validation of a New WHO Concept for Healthy Aging in a Longitudinal Chinese Study	Investigation the structure of intrinsic capacity in a representative sample of the Chinese population aged 60 years and older.	Journals Of Gerontology Series A-Biological Sciences And Medical	Beard JR	2020	31
8	Integrated care for older people: guidelines on community-level interventions to manage declines in intrinsic capacity	The guidelines on ICOPE offer evidence-based guidance to health care providers on the appropriate approaches at the community level to detect and manage important declines in physical and mental capacities, and to deliver interventions in support of caregivers.	https://www.who.int/publications/i/item/WHO-FWC-ALC-19.1	World Health Organization	2017	30
9	Allostatic load as a biological substrate to intrinsic capacity: a secondary analysis of CRELES	To determine the association of allostatic load with intrinsic capacity.	The journal of nutrition, health and aging	Gutierrez-Robledo LM	2019	27
10	Cross-sectional study examining the status of intrinsic capacity decline in community-dwelling older adults in China: prevalence, associated factors and implications for clinical care	To investigate the prevalence and factors associated with IC decline and examine associations between IC and adverse outcomes among community-dwelling older adults in China.	BMJ Open	Ma LN	2021	27

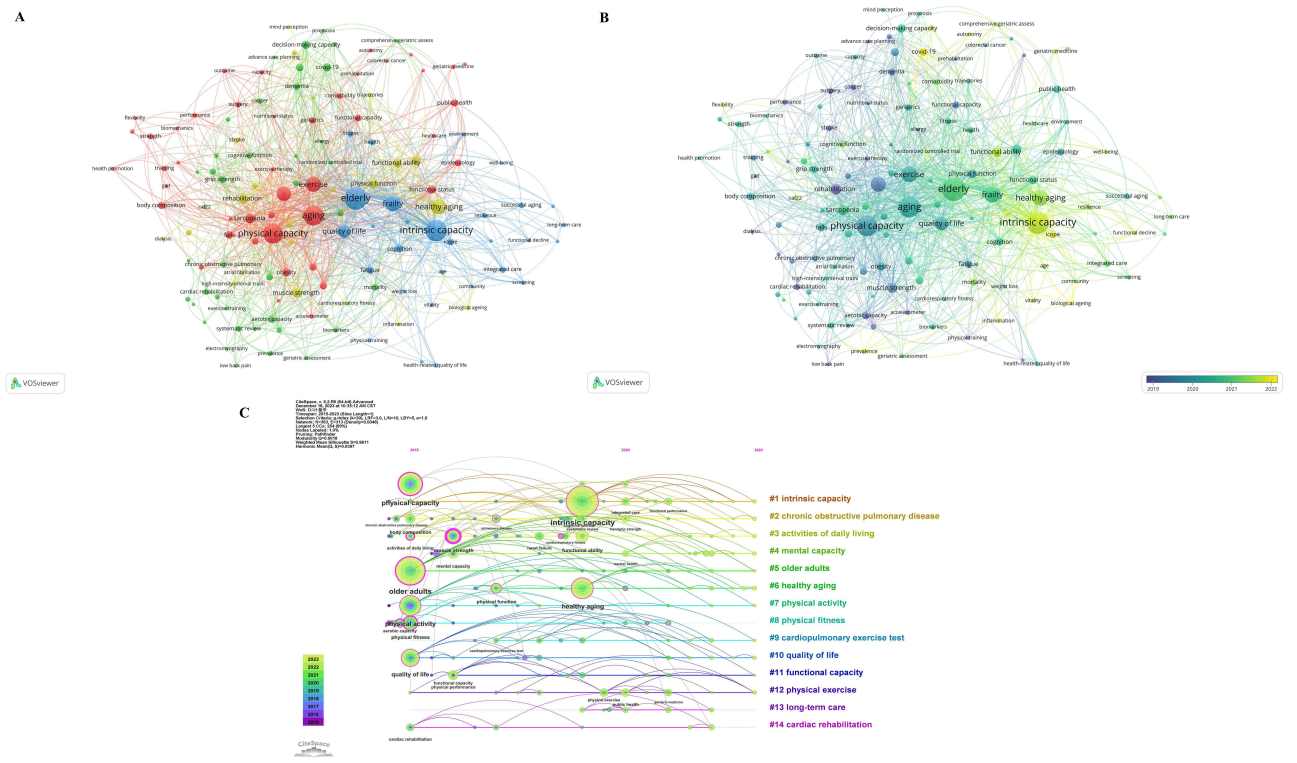

Figure 5 (**A**) Keyword co-occurrence analysis on intrinsic capacity research. (**B**) Overlay visualization of the co-occurrence analysis on intrinsic capacity research. The purple nodes represent the keywords appearing earlier, whereas the yellow nodes reflect the recent occurrence. (**C**) Co-occurrence of temporal trends in keywords.

current data, the annual output of IC researchers has increased over the last eight years, particularly in the last three years, when more than 516 papers were published, indicating that related topics have received more academic focus in recent years. The top three most productive countries were the United States, the United Kingdom, and China.

According to our study, the United States was at the center of research on IC based on the total intensity of cooperation. Additionally, the United States collaborates most closely with the United Kingdom from the perspective of the total intensity of cooperation. Currently, the H-index is the main statistic for measuring an individual's production of scientific articles.[54] Furthermore, past research regarded it as a useful metric for assessing a country's, institution's, or journal's output and effect.[55] Citation statistics from a single country, institution, or journal, like H-index, can be used to assess the quality and academic impact of its publications.[56] Among the top 10 most highly productive institutions, Sweden along with Denmark, the United Kingdom, France, Switzerland, and Italy occupied 80% of the seats, indicating European countries possessed an absolute advantage in this field. From an active aging perspective, further improvements in the amount and quality of IC publications in developing countries are required, although Brazil and China also have a place on this list. As a result, it necessitates the investment of human and financial resources, as well as raising awareness of the need to maintain IC in adults in less advantaged countries/regions. In addition, the research fields analysis indicated that most papers mainly targeted journals in the five fields ①biology and medicine; and ②chemistry and physics; ③psychology and social sciences; ④engineering and mathematics; ⑤ecology and environmental. They mainly cited journals in the areas of i) health, nursing, and medicine; and ii) psychology, education, and social. This may be useful for beginners conducting research in this topic.

TLS indicators, for example, may be used to determine the level of collaboration. Authors, institutions, and countries with greater TLS tend to collaborate more. According to the network map of institution co-authorship analysis, the University of Copenhagen has close relationships with the University of Southern Denmark, supporting Denmark as a center of research. Low-density maps, on the other hand, suggested that research groups were comparably dispersed among institutions, and interinstitutional collaboration has to be strengthened. For author co-authorship analysis, Cesari

Matteo from the United States with the most publications, followed by Qaisar Rizwan from the United Arab Emirates, and Barreto Philipe De Souto from France. They are significant in the burgeoning field of IC research as well as their institutions. In terms of centrality, Vellas Bruno, Barreto Philipe De Souto, and Qaisar Rizwan occupied the center of the cooperating cluster. In terms of journals, the International Journal of Environmental Research and Public Health and Journals of Gerontology Series A-Biological Sciences and Medical were the two most influential, placing first in the most productive journals and first in the most cited journals, respectively. In terms of the top 10 active journals and the top 10 co-cited journals, European journals both had a larger share of the total (80%).

Research Status of IC

Citations may be the most essential bibliometric feature of a study because they signify its relevance and prominence among academics. In this analysis, the top ten cited sources were chosen to identify the IC knowledge base. The top ten publications covered a variety of themes. Overall, four of these documents were focused on the application scenarios of IC; and six studies were related to the theoretical framework. In 2016, Beard et al published the most highly cited paper.[3] The main contribution of this report was reviewing current knowledge and gaps providing a public health framework for action on aging and health and redefining healthy aging based on functional ability. WHO has established the notion of healthy aging as the process of building and maintaining the functional ability essential for older persons to live a healthy life to formulate public health strategies in response to the aging population. Despite evidence suggesting focusing on IC in older adults is more successful than focusing on specific chronic conditions. The field of IC evaluation and intervention development is still in its infancy.[9]

Literature co-citation analysis identifies the underlying intellectual structure and knowledge roots of a specific domain.[57] In this study, the top ten co-cited references were chosen to evaluate the knowledge base connected to the IC landscape. As a whole, most of these references were experimental research and only three studies were reviews or commentary;[5,15,58] sixty percent of the top co-cited references were focused on the theoretical basis including concept definition, comparison, validity, and theoretical framework models,[5,6,15,52,53] the other forty percent of the references were more focused on the different dimensions or clinical utility of screening tool.[11,16,59–61] "Evidence for the domains supporting the construct of intrinsic capacity" by Cesari et al[5] which was one landmark study, the five IC domains were introduced and developed in this research. It triggered the subsequent research on the evaluation of IC. Another survey study by Beard et al,[11,52] which reported the results of the national survey that five subfactors (psychological, sensory, cognitive, vitality, and locomotor) formed a structure to better predict future functioning in English and Chinese longitudinal studies, respectively. Based on these investigations, researchers from various nations assessed and validated the predictive validity of IC decline and its dimensions in older adults. Other studies have focused more on enriching and extending the theoretical boundaries and measurement tools associated with IC. Basic theoretical advances in IC research are now opening the path for practice and clinical application. In this regard, additional future study is required because there are few influential empirical studies in this area.

Perspectives

Some noteworthy Perspectives on IC indexed by the WOSCC database between 2015 and 2023 were offered in this study. Hotspots in the field can be reasonably described by keywords. According to VOSviewer analysis, the identified keywords with the latest AAYs, such as "biological aging", "ICOPE", "Covid-19", "prevention", "inflammation", and "CAF22" may become the research hot spots. The transformation of the research field was in the context of healthy aging in the post-COVID-19 era. The overlapping crises of intensive aging and the pandemic over the past few years have had an unprecedented impact, which raises the need to undergo the continuous, detailed monitoring and maintenance of IC and resilience for old adults in both the public and private spheres. In light of this, the academic community appears to be paying particular attention to research approaches shifting from disease-centered to function-centered in the current specific macro environment. The measurement of IC may provide a unique technique for persuading individuals to adopt healthy lives since it represents an individual's biological aging process.[9] It is essential to develop tailored care plans that integrate strategies for reversing, delaying, or preventing further IC decline. To address the adverse events caused by IC decrease, WHO developed the ICOPE recommendations to control IC decline in 2017.[6] In 2019, the WHO also released

the Handbook: Guidance on Person-Centered Assessment and Pathways in Primary Care to assist community health and care workers in implementing the ICOPE recommendations.[62] Meanwhile, several studies have been performed to explore possible molecular mechanisms of IC decrease, including chronic inflammation and neuromuscular mechanisms.[63–65] However, studies on the identification of IC biomarkers are still rare.[9] Therefore, as the research has gradually developed from macro to micro, it can be predicted that the research on the biomarkers for IC decline will continue to be a research hotspot.

(i) Biological aging. Individual aging processes vary greatly. The concept of IC reflects this variety by representing the overall physical and mental state, therefore more correctly assessing the individual health-related biological aging process than the more common measure of chronological age.[66] Recent research has found considerable relationships between health dimensions and biological aging phenotypes, including autophagy, mitochondrial function, cellular senescence, and DNA methylation.[67] Some scholars found that plasma biomarkers of two hallmarks of aging (chronic inflammation and mitochondrial dysfunction) differentiated older adults with multi-impaired IC trajectories from those with high-stable IC.[64] The routine evaluation of biological age using measures such as IC could have provided a more comprehensive insight into the vulnerability and resilience of the individual.

(ii) ICOPE. In 2017, WHO released the ICOPE Guidelines to promote healthy aging and maintain older people's independence.[7] The WHO's proposal is based on IC concepts. Prior studies have used the ICOPE screening tool with retrospective data, but there is limited evidence on its feasibility, accuracy, and usefulness from real-life perspective studies.[28] A recent WHO report analyzed ICOPE pilot projects in different countries (France, Andorra, China, and India) and showed that ICOPE is feasible in a variety of contexts, from high-income countries to low-income countries.[68] More research is needed on the ICOPE approach and IC framework to identify individuals at risk for care dependency in various populations.

(iii) Covid-19. The Covid-19 pandemic has greatly altered the living environment for older adults with lock-downs, social distancing, and fragmented care. Some scholars predict that when the pandemic is over, it is likely that accelerated aging will be observed in many people, regardless of whether they are infected with covid-19, and this phenomenon is likely to be most obvious in older adults.[69,70] Several studies have investigated the trajectory of an individuals' intrinsic abilities during the pandemic to better guide clinical decision-making and suggest targets for intervention.[71,72] During the post-epidemic era, the widespread implementation of the IC model has the potential to facilitate the modernization of our healthcare systems and enhance their alignment with individual needs.[73]

(iv) Inflammation. It is important to understand the mechanisms for IC decline, find reliable markers to track this decline, and set intervention goals to maintain function and promote healthy aging. Recent studies have indicated that heightened levels of plasma inflammation biomarkers, including IL-6, CRP, TNFR-1, and GDF-15, have been linked to decreased IC or accelerated IC decline.[64,74] Chronic inflammation is the most convincing biomarker of frailty in the context of "inflammatory aging" so far.[75] However, research on anti-inflammatory treatments for improving IC is limited. More research is needed to understand the connections between multiple inflammatory biomarkers and IC, as well as the effectiveness of anti-inflammatory treatments in improving IC.

Strengths and Limitations

The current study has several strengths. First, for the first time, bibliometric analysis was used to provide a detailed insight into the dynamic development process, research hotspots, research trends, and milestone articles of IC over the past eight years. Second, the current study was carried out in parallel utilizing two widely used bibliometric software programs, allowing us to obtain more thorough and reliable analytical results. However, there are several limitations to this study that are inherent in bibliometrics. First, as in prior studies,[76,77] data were retrieved solely from the WOSCC database, which may result in some publications being missed. Nonetheless, the WOSCC database is the most commonly utilized for scientometric analysis.[43] Other databases, such as Scopus and Google Scholar, may be valuable in assessing and comparing their findings to these. Second, while our retrieval approach only included a few precise terms about the major target objects and conditions, the articles returned may contain false positives and false negatives, given that no search query is 100% perfect. Third, this study is dependent on CiteSpace and VOSviewer, and the search algorithm is not flawless and may introduce

bias.[78] Finally, we only included English-language papers, which may have left out some important research investigations. Despite these limitations, our findings provide a robust global view of IC during the last eight years, which may be useful in providing an illuminating perspective on present research and directing future studies in this field.

Conclusions

In this paper, we present an overview of the current state of IC research in older persons around the world and highlight developing trends. The relevant study subject is rapidly developing and garnering more attention from academics. European countries dominate this subject in terms of both the total number of articles and the total number of citations. More widespread global collaboration, particularly among developing countries, may be required. Studies on biological aging, ICOPE implementation, post-COVID-19 syndrome, and biomarkers, in particular, will be the next possible research frontiers as the focus shifts from disease-centered to function-centered. Furthermore, various future research directions must be addressed. First, it may be necessary to focus more on IC in non-Western societies since they are native community contextual factors mediated and require different theoretical approaches. Second, more focus may be placed on the possibilities for evaluating, monitoring, and promoting developing technologies such as digital health technology and genetic diagnosis and therapy. Finally, research into the effective use of IC research outcomes is required.

Abbreviations

IC, intrinsic capacity; WHO, World Health Organization; ICOPE, Integrated Care for Older People; WOSCC, Web of Science Core Collection; IF, Impact Factor; JCR, Journal Citation Reports; TLS, Total link strength.

Data Sharing Statement

The raw data supporting the Conclusions of this article will be made available by the author (Xia Cao), without undue reservation.

Ethics Approval and Consent to Participate

This study did not require the approval of an ethics committee since we analyzed a secondary database.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests in this work.

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