Visualization Analysis of Research Hotspots and Frontiers in Unsteady Load Studies Using CiteSpace: Postprint

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Abstract

Background Allostatic load is a multisystem physiological indicator that measures chronic stress in the body, reflecting the cumulative physiological burden of chronic stress exposure on the body, and is of significant importance for the prevention and treatment of chronic diseases. In recent years, research on allostatic load has been gradually increasing, but domestic research development has been relatively slow. Reviewing the literature on allostatic load to comprehensively understand the development trends and hotspots in this field can help promote innovative development in allostatic load research in China.

Objective To understand the research hotspots and frontiers in this field by analyzing recent literature on allostatic load, providing references for future research.

Methods Literature on allostatic load published from database inception to December 1, 2022 was retrieved from the Science Citation Index Expanded (SCIE) database in the Web of Science Core Collection. Microsoft Excel 2019 and CiteSpace software were applied for visual analysis of publication volume, countries, authors, institutions, and keywords.

Results A total of 509 articles were included, with annual publication volume showing a slow growth trend. The United States ranked first in both publication volume (315 articles) and betweenness centrality (0.65). The top three authors by publication volume were JUSTER from Canada (23 articles), SEEMAN from the United States (16 articles), and KARLAMANGLA from the United States (12 articles). The top three institutions by publication volume were the University of California, Los Angeles in the United States (39 articles), the University of Montreal in Canada (21 articles), and the University of Michigan in the United States (20 articles). High-frequency keywords included allostatic load, stress, health, socioeconomic status, and cumulative biological risk. In keyword

burst analysis, the keyword with the highest burst strength was blood pressure (burst strength of 5.8).

Conclusion Research on allostatic load is gradually becoming a new academic hotspot, with research focuses primarily on the influencing factors of allostatic load and its association with health outcomes; intervention studies are extremely scarce. Development in this field in China still requires further exploration. Future research may consider expanding the scope of study populations, developing allostatic load measurement methods tailored to different populations and establishing standards, as well as conducting relevant intervention studies to promote human health.

Full Text

Visualization Analysis of Hotspots and Frontiers in Allostatic Load Research Based on CiteSpace

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Abstract

Background: Allostatic load (AL) is a multi-system physiological indicator for measuring chronic stress in the body, reflecting the cumulative physiological burden of chronic stress exposure. It holds significant importance for the prevention and treatment of chronic diseases. While AL-related research has been gradually increasing in recent years, domestic research development in this area remains slow. Reviewing AL literature to comprehensively understand development trends and hotspots in this field will facilitate innovative development of AL research in China.

Objective: To understand research hotspots and frontiers in the AL field and provide reference for future research by analyzing relevant AL literature published in recent years.

Methods: The Science Citation Index Expanded (SCIE) database of Web of Science Core Collection was searched for literature on AL from inception to December 1, 2022. Microsoft Excel 2019 and CiteSpace software were applied to conduct visualization analysis of publication volume, countries, authors, institutions, and keywords.

Results: A total of 509 articles were included, showing a slowly increasing trend in annual publication volume. The United States ranked first in both annual publication volume (315 articles) and betweenness centrality (0.65). The top three authors by publication volume were JUSTER from Canada (23 articles),

SEEMAN from the United States (16 articles), and KARLAMANGLA from the United States (12 articles). The top three institutions by publication volume were the University of California, Los Angeles (39 articles), University of Montreal in Canada (21 articles), and University of Michigan in the United States (20 articles). High-frequency keywords included AL, stress, health, socioeconomic status, and cumulative biological risk. Blood pressure was the keyword with the strongest citation burst (burst strength = 5.8).

Conclusion: AL research is gradually becoming a new academic hotspot, focusing primarily on influencing factors of AL and its associations with health outcomes, with intervention studies being extremely rare. Development in this field in China still requires further exploration. Future research should consider expanding the scope of study populations, developing standardized AL measurement methods for different populations, and conducting relevant intervention studies to promote human health.

Keywords: Allostatic load; Stress, psychological; Chronic stress; Bibliometrics; Visualization

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Allostatic load (AL), first proposed by McEwen and Stellar in 1993, refers to the cumulative wear on various physiological systems resulting from prolonged exposure to repeated or chronic stress [1-2]. As an objective indicator for measuring chronic stress, AL incorporates biomarkers from multiple stress-regulatory systems, including cardiovascular, metabolic, endocrine, and immune systems, playing a crucial role in research exploring the effects of stress on physical and mental health [3-4]. It has gradually become a research hotspot in recent years. International research on AL started earlier and has produced substantial literature, establishing that AL is closely associated with a wide range of health outcomes, including but not limited to cardiovascular disease, diabetes, musculoskeletal disorders, cancer, periodontal disease, mood and anxiety disorders, and post-traumatic stress disorder [5-9]. However, domestic research on AL remains relatively limited in both quantity and scope. Therefore, this study aims to analyze relevant literature in the field of AL from the Web of Science database using CiteSpace software to understand research hotspots and development trends, thereby providing reference and guidance for future AL research in China.

1.1 Literature Retrieval and Screening

The Science Citation Index Expanded (SCIE) database of Web of Science Core Collection was selected as the data source. A topic search was conducted using the search strategy: "((TS=(allostasis)) OR TS=(allostatic load)) OR TS=(allostatic loads)" . The retrieval timeframe spanned from database inception to December 1, 2022. Literature screening strictly adhered to inclusion and exclusion criteria, with two researchers independently conducting the search. Inclusion criteria were: (1) English-language literature published internationally;

(2) articles with AL as the research content; (3) human subjects. Exclusion criteria were: (1) duplicate publications; (2) literature from conferences, newspapers, letters, news reports, etc.

1.2 Analysis Tools

CiteSpace software is commonly used in China and supports analysis of foreign literature with rich functionality [10]. This study employed CiteSpace visualization analysis software to analyze authors, institutions, countries, keywords, and other aspects of the retrieved literature, generating visual maps to provide an intuitive understanding of the current state and development trends in this research field.

1.3 Research Methods

The flowchart in Figure 1 [Figure 1: see original paper] illustrates the literature screening and analysis process. A total of 2,186 articles were retrieved from the Web of Science Core Collection database. After screening titles, abstracts, and full texts, 1,677 articles that clearly did not match the topic were excluded, resulting in 509 articles for inclusion. Data cleaning was performed using CiteSpace' s "Remove Duplicates" function to eliminate potential duplicate records, and the deduplicated data were then imported into the software.

CiteSpace parameter settings were as follows: Time Slicing: 2004-2022; Years Per Slice: 1; Link strength: Cosine; Threshold selection: g-index; Pruning algorithm: Pathfinder; Clustering algorithm: LLR. Node types were selected for different analyses: "Country" for national/regional collaboration visualization, and "Keyword" for keyword co-occurrence, clustering, and burst detection analyses. The results were presented in tables and knowledge maps with textual summaries.

2 Results

2.1 Literature Retrieval Results

A total of 2,186 articles were retrieved, and after screening titles, abstracts, and full texts, 1,677 articles that clearly did not match the theme were excluded, with 509 articles ultimately included. The literature screening flowchart is shown in Figure 1 [Figure 1: see original paper].

2.2 Publication Volume Analysis

From 2004 to 2022, 509 articles related to AL research were retrieved. The publication volume in the AL field gradually increased from 2004. Based on the growth trend, two stages can be identified: 2004-2008 as a slow period, where publication volume initially increased then decreased to the level of the initial year; and 2009-2022 as a rapid growth period, where publication volume surged from 4 to 62 articles, peaking in 2020. Publications from the most recent eight

years (2015-2022) accounted for over 70% (372/509) of the total publications from 2004-2022, showing an overall fluctuating upward trend (Figure 2 [Figure 2: see original paper]).

2.3 Author and Institution Analysis

From 2004 to 2022, a total of 487 authors and 337 institutions participated in AL research internationally. Among the top 10 authors by publication volume (Table 1), three scholars published $ $10 articles: JUSTER (23 articles), SEEMAN (16 articles), and KARLAMANGLA (12 articles). In terms of citation frequency, LUPIEN (13,379 citations), SEEMAN (11,925 citations), and KARLAMANGLA (8,730 citations) ranked top three in total citations. Combined with h-index data, these three scholars' research papers have significant academic influence in the AL field and are widely recognized by peers.

Among the top 10 institutions by publication volume (Table 2), the University of California, Los Angeles, University of Michigan, University of Maryland, Carolina University, Harvard University, and The Ohio State University are all located in the United States, with their combined publications exceeding 20% of the total literature.

2.4 Country/Region Analysis

Using CiteSpace software with node type set to "Country," a national/regional collaboration network map was generated (Figure 3 [Figure 3: see original paper]), comprising 52 nodes and 92 connections, with 509 articles from 47 countries/regions. Table 3 lists the top 10 countries/regions by publication volume, with the top five being the United States (315 articles), Canada (61 articles), United Kingdom (56 articles), Germany (25 articles), and Italy (25 articles).

China ranked sixth with 24 publications and a centrality of 0.01. Based on both publication volume and centrality, the United States and United Kingdom are the primary countries conducting AL research, maintaining close collaborations with other nations. China' s publication volume is modest, with no institutions ranking in the top 10 and low centrality, indicating that Chinese AL research institutions are relatively dispersed and diverse. This suggests that Chinese scholars need to strengthen collaborative research both within teams and internationally, broaden research scope, and enhance research depth.

2.5.1 Keyword Co-occurrence Analysis

Keyword co-occurrence analysis was performed using CiteSpace with node type set to "Keyword," generating a keyword co-occurrence network map (Figure 4 [Figure 4: see original paper]) comprising 474 nodes and 3,179 connections. Beyond keywords related to the search strategy such as "allostatic load (AL)," "allostatic load index," "allostatic score," "allostasis," "allostatic overload," and "allostatic load score," the top 20 keywords by frequency are detailed in Table 4 .

The most frequent keyword was "stress" (173 occurrences). Keywords with centrality >0.1 included "association," "corticotropin releasing hormone," "chronic stress,""body mass index,""pituitary adrenal axis,""1st episode psychosis,""adaptation,""disease,""depression,""adverse childhood experience,""age,""3rd national health," "cardiovascular disease," "bipolar disorder," "cumulative biological risk," and "self rated health," indicating these high-centrality keywords are crucial connecting concepts in the field.

2.5.2 Keyword Clustering Analysis

Using the LLR algorithm for keyword clustering analysis, closely related keywords were grouped into clusters, with the most representative keywords selected as cluster labels. A total of 17 clusters were identified (Figure 5 [Figure 5: see original paper]). The modularity Q value was 0.749 (>0.3) and the mean silhouette value was 0.875 (>0.7), indicating significant cluster structure and credible results [11]. Analysis of the 17 cluster labels revealed that AL research primarily focuses on three themes: (1) Influencing factors of AL: #1 immigration, #3 socioeconomic status, #9 chronic stress, #12 psychosocial stress, #13 african immigrants, #14 relative income. (2) Common research methods and key populations: #0 cohort study, #8 adolescent health. (3) Adverse effects of AL throughout the life course, primarily manifested as disease impact: #2 risk factor, #4 cardiovascular disease, #5 schizophrenia, #6 disease, #7 physical impairment, #10 bipolar disorder, #11 cumulative biological risk, #16 cumulative risk.

2.5.3 Keyword Burst Analysis

Based on keyword clustering, burst detection analysis was performed (Figure 6 [Figure 6: see original paper]). In the figure, "Strength" represents burst intensity, while "Begin" and "End" indicate the start and end times of the burst, corresponding to the length of the red segments in the figure. Figure 6 [Figure 6: see original paper] shows the top 29 burst keywords in AL research, with "blood pressure" having the strongest burst intensity. The longest burst duration was "coronary heart disease," persisting from 2005 to 2018 (13 years). Keywords including "association," "biological dysregulation," "exposure," "pathophysiology," "nutrition examination survey," and "symptom" have continued bursting to 2022, suggesting future research may continue developing in directions related to these six terms.

3 Discussion

3.1 Current Status of AL Research

International research on AL has gradually increased from 2004 to 2022. In terms of publication volume, 2004-2008 showed slow development, followed by gradual growth. The year 2018 marked a sudden surge in AL research literature,

indicating growing attention from scholars. A total of 487 authors, 337 institutions, and 47 countries/regions contributed to AL research publications. The most productive author was JUSTER with 23 articles; the most productive institution was the University of California, Los Angeles with 39 articles; and the most productive country/region was the United States with 315 articles. The United States demonstrates substantial research strength and influence in AL research, maintaining close collaborations with other countries. China ranked sixth with 24 publications, with no institutions in the top 10 and low centrality (0.01), indicating that Chinese AL research institutions are relatively dispersed. This suggests Chinese scholars need to strengthen collaborative research within teams and internationally, broaden research scope, enhance research depth, and pursue studies on AL pathophysiological mechanisms, exposure factors affecting AL, and AL intervention research.

3.2 Research Hotspots in AL

Based on keyword co-occurrence, clustering, and burst analyses, current AL research primarily focuses on exploring influencing factors, associations with various diseases, selection of relevant biomarkers, and different study populations including general populations (elderly, adults, adolescents) and special populations (patients with Alzheimer' s disease, schizophrenia, cancer, depression, and pregnant women).

3.2.1 Studies on Influencing Factors of AL

AL represents the cumulative physiological response to chronic stress exposure. Recent AL research has increasingly explored influencing factors, primarily including sociodemographic factors such as socioeconomic status [12], relative income level [13], gender [14], and racial differences [15], as well as daily life events [16], health behaviors, and coping strategies [17-18].

3.2.2 Studies on AL Associations with Multiple Diseases

The AL theory proposed by McEwen and Stellar provides a scientific framework for explaining the relationship between chronic stress and health outcomes [1-2]. This theory elucidates that when the body is chronically exposed to stress, the hypothalamic-pituitary-adrenal axis is activated, leading to sustained secretion of stress hormones that weaken the body' s protective capacity. Various physiological systems experience different degrees of wear, with parameters related to metabolic (e.g., total cholesterol, HDL, waist-to-hip ratio), cardiovascular (e.g., systolic and diastolic blood pressure), and immune (e.g., C-reactive protein) systems reaching subclinical levels. Dysregulation across multiple physiological systems to a certain extent leads to disease occurrence and mortality [1-2]. Consequently, numerous studies have examined the relationship between AL and health status/outcomes [19], including but not limited to chronic diseases [5-9,20], preterm birth [21], pain [22], and mortality [23].

3.2.3 Studies on AL Measurement Methods

Seeman et al.' s [24] study investigating the association between AL and aging in older adults (the MacArthur Study of Successful Aging) was the first empirical study following the proposal of AL theory. This study demonstrated that elevated AL effectively predicts cognitive and physical decline and increased cardiovascular disease risk in older adults, establishing the operational definition of AL. The study used ten biomarkers as AL index measures: 12-hour urinary cortisol, epinephrine and norepinephrine output, serum dehydroepiandrosterone sulfate, total cholesterol, HDL cholesterol, plasma glycated hemoglobin, total systolic blood pressure, diastolic blood pressure, and waist-to-hip ratio.

As AL research has expanded with diverse study populations and purposes, researchers have employed varying measurement methods for AL, with differences in selected biomarkers [25-26], resulting in heterogeneity across studies in the number, combination, and assessment methods of AL indicators [27]. While Seeman et al.' s [24] study established the initial measurement method for AL in older adults, the applicability of these measures to other age groups requires further investigation. Accortt et al.' s [26] study on AL in pregnant women found that incorporating vitamin D deficiency into the AL index strengthened its association with perinatal health outcomes. Therefore, how to select scientifically reasonable biomarkers as AL measurement indicators for different study populations is receiving increasing attention from scholars.

3.3.1 Evolution of Study Populations

Research has evolved from initially focusing on AL and aging in older adults [24] to include adults [12], children/adolescents [28-30], pregnant women [26], workers in different occupations [31-33] (e.g., healthcare workers, teachers), and patients with various diseases [7-8]. Emerging research areas focusing on children/adolescents and pregnant women are exploring associations between AL and physical function/disease risk [28-30,34-35]. Although current research remains limited, it demonstrates that future studies will conduct in-depth exploration across more diverse populations to further clarify AL' s important role throughout the life course.

3.3.2 Measurement Standards for AL Across Different Populations

As AL research deepens with diverse study populations and objectives, scholars have employed different measurement methods. Overall, there is a lack of "gold standard" for AL assessment. Future research should focus on exploring appropriate AL measurement indicators for different populations, establishing standardized operational definitions of AL, and creating a scientific, standardized, and unified AL assessment system to improve evidence quality and enable comparison across studies, thereby generating robust evidence to guide clinical practice.

3.3.3 Further Exploration of Pathophysiological Mechanisms

The main burst keywords in 2022 AL research were "blood pressure," "biological risk," and "cumulative biological risk." Keywords that have continued bursting to 2022 include "association," "biological dysregulation," "exposure," "pathophysiology," and "symptom." Current research has only established that AL is closely associated with the hypothalamic-pituitary-adrenal axis, but the specific mechanisms remain unclear [36]. The burst timeline suggests that future AL research should further explore pathophysiological changes from AL development to disease stages, upon which intervention studies can be conducted to slow physical decline and inhibit disease onset and progression.

This study employed CiteSpace software to analyze research hotspots in AL from SCI-indexed journals, aiming to provide reference for domestic practice and research. Results indicate that while China' s publication volume in the AL field is modest, research breadth and depth should be enhanced, inter-institutional collaboration strengthened, and research evidence quality improved. This study has limitations: due to the scarcity of AL research literature in Chinese databases, which weakens the feasibility of bibliometric analysis, only foreign-language databases were selected for analysis. In conclusion, within the context of the "Healthy China" strategy, AL' s value lies in revealing complex mechanisms through which chronic stress affects physical and mental health, making AL research highly valuable for application.

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Note: Figure translations are in progress. See original paper for figures.