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Nudging toward Physical Activity: a Bibliometric Analysis and Future Scopes

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ABSTRACT

Physical inactivity is a major risk factor for non-communicable diseases (NCDs) and mortality. Encouraging individuals to be more physically active is a crucial strategy for reducing these health risks. In this context, understanding the hidden drivers behind people's mobility preferences is particularly important. Researchers use nudges as a behavioral tool to describe effective motivations in decision-making and choices, which can lead to predictable outcomes without excluding alternative options or relying on financial incentives. Using nudges in real-world conditions to promote physical activity has been the subject of various studies. However, there is still a lack of understanding of the current state and future research directions. To address this gap, this paper utilizes a bibliometric tool to analyze 119 nudge-related studies in the field of physical activity published in Scopus, providing a comprehensive overview of their structure, themes, and conceptual evolution. The analysis showed an increasing trend in research on nudges and physical activity, with a notable number of publications in 2023, especially in the field of medicine. American and European researchers have made substantial contributions, highlighting the importance of both individual and public health in developed nations. The ability of health-oriented tools to promote physical activity has also been emphasized, and some studies have investigated nudge theory in both nutrition and physical activity simultaneously. The results show that the topic of nudges and physical activity is a new interdisciplinary research area with practical implications for public health policy, and there is also considerable potential for further research in this field.

Introduction

Physical inactivity remains a major global concern, significantly contributing to the prevalence of non-communicable diseases (NCDs) such as cardiovascular disease, cancer, and diabetes (Strain *et al.*, 2020).

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These health conditions are a leading cause of death worldwide, and their prevalence continues to rise. According to the World Health Organization (WHO), one in every four adults and more than 80% of adolescents do not engage in adequate physical activity, resulting in approximately 3.9 million premature deaths each year (WHO, 2022a). Moreover, the WHO projects that from 2020 and 2030, around 500 million people will suffer from NCDs as a result of physical inactivity, leading to an economic burden estimated at USD 27 billion annually (WHO, 2022c). This data underscores the urgent need for effective interventions to promote physical activity and reduce the risk of NCDs (Singh *et al.*, 2011, p. S23).

Recognizing the urgency of this global health challenge, there is an increasing focus on developing behavioral interventions to foster physical activity. Among various interventions, "nudging" has gained considerable attention as a cost-effective and scalable approach (Costa *et al.*, 2024, p. 2; WHO, 2022b). Nudging, rooted in behavioral economics, involves subtle changes in the environment or choice architecture that influence people's behavior in a predictable way without restricting their freedom of choice or significantly altering economic incentives (Thaler & Sunstein, 2008). This concept relies on the understanding that human decision-making is often guided by automatic, fast-thinking process (System 1), as opposed to deliberate, slow-thinking process (System 2) unengaged (Banerjee & John, 2024, p. 69). By tapping into theses automatic processes, nudges can encourage healthier behaviors, such as increased physical activity, without requiring conscious, effortful decision-making (Hallsworth, 2017).

Research on the application of nudging to promote physical activity has expanded rapidly (Chen *et al.*, 2023; Jia & Mustafa, 2022; Murayama *et al.*, 2023; Serper *et al.*, 2024). Studies have explored various nudging strategies, such as prompts, reminders, social comparisons, and environmental cues, to enhance physical activity levels across different settings. For example, Forberger *et al.* (2022) highlighted 26 studies using nudge-related interventions to stimulate physical activity and discourage sedentary behavior in the workplace. These interventions often targeted activities like stair climbing and walking, using tactics like chair sensors and software packages. In the other study, Forberger *et al.* (2019) identified 35 publications that implemented point-of-choice prompts in public spaces such as railway stations, shopping malls, and airports to encourage physical activity.

Garland *et al.* (2018) utilized design elements like color, priming, and social norms to encourage and facilitate physical activity engagement. Peacock *et al*. (2020) found that pets, specifically dogs, acted as effective nudges, significantly reducing sedentary behaviors among older adults. Moreover, Additionally, innovative tools like the College Physical Activity Nudges Susceptibility Scale (CPANSS) by Wang *et al.* (2022) have been designed to aid policymakers in crafting effective nudges to promote physical activity in college settings. Additionally, Van der Meiden *et al.* (2019) highlighted the effectiveness of footprints as nudging interventions in increasing stair use among employees.

Despite the growing body of research on nudging and physical activity, there remains a gap in understanding the overall pattern, trends, and thematic clusters within this field. Although existing systematic reviews and meta-analyses (Hummel & Maedche, 2019; Last *et al.*, 2021; Ledderer *et al.*, 2020; Mertens *et al.*, 2022; Möllenkamp *et al.*, 2019; Yoong *et al.*, 2020) provide valuable insights, they often concentrate on a specific aspect of the current state of research (Ioannou *et al.*, 2021, p. 2; Jia & Mustafa, 2022, p. 3; Reñosa *et al.*, 2021, p. 2) and seldom offer a comprehensive overview of the evolution and patterns in contemporary nudge research (Jia & Mustafa, 2022, p. 2). Consequently, a holistic overview of the evolution and patterns in contemporary nudge research, particularly in the context of physical activity, is lacking. Furthermore, little is known about the dominant research disciplines and potential future research directions in this area. Addressing these

gaps is essential for developing effective nudging strategies to promote physical activity and improve public health outcomes.

To address the existing knowledge gap, this study conducts a bibliometric analysis of relevant studies on nudges and physical activity using VOSviewer. Bibliometric analysis can assist researchers in comprehending large volumes of scientific data, offer visualizations to highlight areas that have made substantial progress, and outline potential future research directions based on this data (Donthu, Kumar, Mukherjee, *et al.*, 2021, p. 285). Therefore, the primary object of the study is to enhance the understanding of the structure and dynamics of knowledge within the fields of nudging and physical activity. By identifying key trends, influential studies, and research gaps, this study aims to facilitate well-informed decisions regarding the design and implementation of nudging interventions. The findings will also provide valuable insights for healthcare researchers and policymakers, guiding the development of innovative and effective strategies to promote physical activity and reduce the burden of NCDs.

Methodology

Bibliometric analysis has emerged as a valuable tool for addressing the limitations of traditional narrative literature reviews in the context of large-scale scientific research (Jia & Mustafa, 2022, p. 3). By providing an objective and quantitative approach, bibliometric analysis enables researchers to evaluate academic contributions, assess the merits of studies, and identify emerging research trends. (Donthu, Kumar, Pandey, *et al.*, 2021, p. 759). As the availability and usability of bibliometric software and scientific databases have improved, this method has become increasingly widespread across various disciplines, offering a more reliable and comprehensive analysis of scientific literature (Jia & Mustafa, 2022, p. 3). Consequently, bibliometric analysis is transforming the way that researchers synthesize and evaluate knowledge, offering a powerful complement to traditional review methods.

Scopus was chosen as the scientific database for this bibliometric investigation. It is a highly popular resource for peer-reviewed literature, encompassing scientific journals, books, and conference proceedings (Scopus, 2022). The search strategy focused on identifying articles that addressed both nudging and physical activity.

Based on publication type and language, articles, conference papers, and reviews in English-language were considered. The study's search was carried out in January 2024 and was restricted to materials published from 2008 until the end of January 2024. The year 2008 was selected as the publications' starting point due to the introduction of the nudge technique by Thaler and Sunstein (2008) in their work published in the same year. The following keywords (or their derivatives) were used as the search criteria[1]: Nudg* or "Choice Architecture*" or "Behav* Economics" and "Physical Activit*" or "Sedentary Behav*" or Sport* or "Health* Behav*". Documents that were not deemed relevant to both nudging and physical activity based on their title and abstract were excluded.

Based on the research criteria, a total of 810 references were generated. Afterwards they were sorted according to their category, which included articles, conference papers, and reviews written in English. At this step, a total of 138 references were eliminated. Subsequently, documents that were not relevant to both nudges and physical activity were excluded by assessing their titles and abstracts, resulting in the removal of 553 documents. Ultimately, all the relevant details of the remaining 119 documents, such as title, abstract, keywords, sources, and affiliations were collected from the Scopus scientific database for further investigation.

VOSviewer was used to generate bibliographic analysis results, including visualization, co-citation analysis, and keyword co-occurrence. VOSviewer creates a nodal network visualization. The size of each node and the lines that connect them, represent the intensity of the node and the relationship between nodes, respectively. Larger nodes and thicker lines signify stronger

[1] The incomplete writing and the use of asterisks for some terms are because the database search engine considers all their derivatives.

connections and more intense relationships, offering a clear visual representation of patterns within the academic literature (Donthu *et al.*, 2020),

Figure 1 shows the PRISMA flowchart of this study, based on the search, filtering, and data processing criteria listed above.

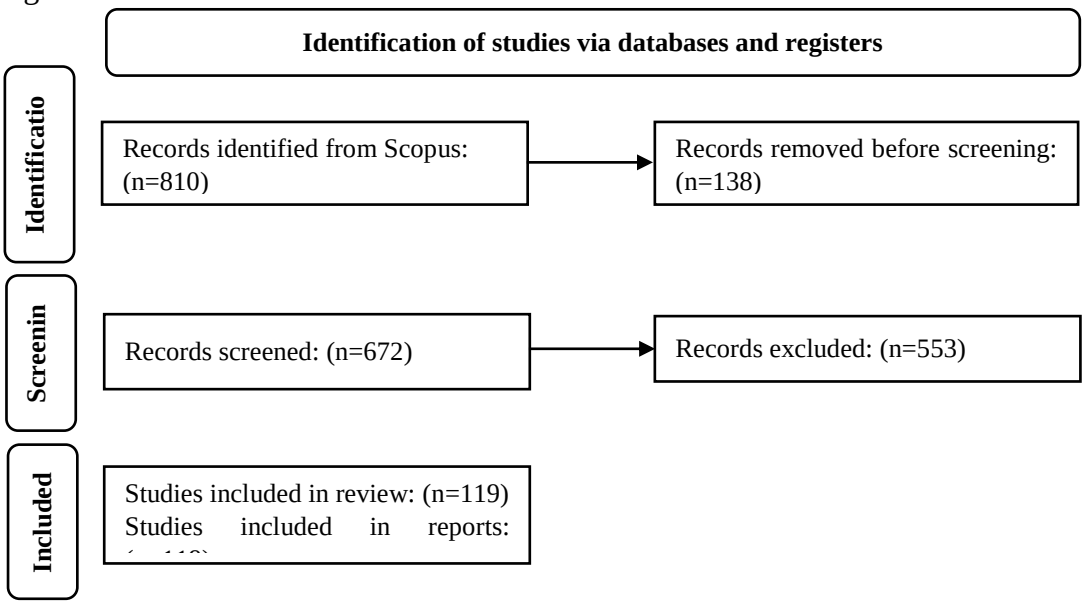

Figure 1. The PRISMA flowchart of the study

Results

Yearly Publication

Figure 2 displays the annual output of publications concerning nudges and physical activity. The results show that there were no studies identified in 2008. Thaler and Sunstein (2008) introduced the nudge approach in their book "Nudge: Improving Decisions About Health, Wealth and Happiness". This suggests that academics had insufficient knowledge and confidence in this domain until further studies were conducted, which could explain the lack of related studies in Scopus throughout 2008. Overall, the figure suggests that there is a growing interest in the research on nudges and physical activity. Since 2009, there have been several publications, with fewer than five studies published per year until 2016. However, there was a significant increase in 2018, probably due to Thaler obtaining the Nobel Prize in Economics for his contributions to behavioral economics, nudge strategy, and choice architecture the previous year.

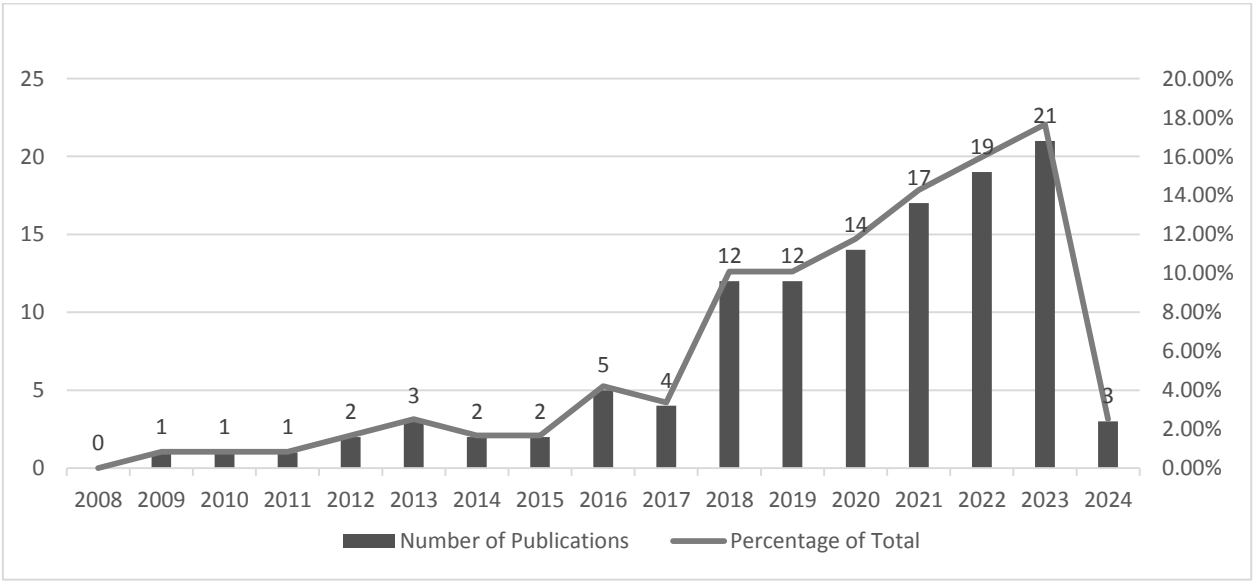

Figure 1. Published yearly output of nudges and physical activity in Scopus.

The figure also shows a fixed rate of publications in 2019, which could be due to the influence of the COVID-19 pandemic and associated restrictions on research activities. From 2020 to 2023, there was a small but steady increase in publications, indicating a renewed interest in the use of the nudge strategy in promoting physical activity. While the precise number of publications in 2024 cannot be estimated due to the timing of the research, it is noteworthy that more than 80% of the studies emerged within the past seven years. Moreover, given the current upward trajectory in publications over the last five years, it is reasonable to anticipate a continued expansion in research efforts within this burgeoning field.

Document Type

Table 1 presents publications what were categorized by type. The findings indicate that articles comprised 68.1% (N=81) of the overall total, and conference and review papers constituted 15.1% (N=18) and 16.8% (N=20), respectively. These findings suggest that researchers have primarily focused on articles and it is worth noting that the current data shows less than 100 articles on this topic. Notably, Jia and Mustafa (2022) found a mere 1706 publications on the nudge technique on the Web of Science, highlighting the scarcity of research conducted on this topic between 2012 and 2022.

Table 1. Publications categorized by document type

Type of Publications	Number of Publications	The Proportion of Publications (%)
Article	81	68.1%
Conference Paper	18	15.1%
Review	20	16.8%
Total	119	100%

Table 2 lists the top 10 most-cited studies amongst the 119 publications identified on nudges and physical activity. As expected in a relatively new and emerging field, Hollands *et al.* (2013) stands out with the highest citation count of 230 citations, followed by the study of Patel *et al.* (2017) at 136. The remaining studies received fewer than 100 citations. The overall citation landscapes suggests that the field of nudges and physical activity is in its early stages and there is also a vast potential for further research.

Table 2. The top 10 cited studies in the field of nudge approach and physical activity

Title of Publication	Title of Source	Citations
Altering micro-environments to change population health behaviour: Towards an evidence base for choice architecture interventions (Hollands *et al.*, 2013)	BMC Public Health	230
Effect of a game-based intervention designed to enhance social incentives to increase physical activity among families: The BE FIT randomized clinical trial (Patel *et al.*, 2017)	JAMA Internal Medicine	136
Toward a persuasive mobile application to reduce sedentary behavior (Van Dantzig *et al.*, 2013)	Personal and Ubiquitous Computing	95
The Effects of Young Adults Eating and Active for Health (YEAH): A Theory-Based Web-Delivered Intervention (Kattelmann *et al.*, 2014)	Journal of Nutrition Education and Behavior	81
Activity sculptures: Exploring the impact of physical visualizations on running activity (Stusak *et al.*, 2014)	IEEE Transactions on Visualization and Computer Graphics	80
Effectiveness of Behaviorally Designed Gamification Interventions with Social Incentives for Increasing Physical Activity among Overweight and Obese Adults Across the United States: The STEP UP Randomized Clinical Trial (Patel *et al.*, 2019)	JAMA Internal Medicine	79
Loss-framed financial incentives and personalized goal-setting to increase physical activity among ischemic heart disease patients using wearable devices: The ACTIVE REWARD randomized trial (Chokshi *et al.*, 2018)	Journal of the American Heart Association	73

Gamification Use and Design in Popular Health and Fitness Mobile Applications (Cotton & Patel, 2019)	American Journal of Health Promotion	66
Using behavioral economics to promote physical activity (Zimmerman, 2009)	American Journal of Preventive Medicine	57
Nudging to move: A scoping review of the use of choice architecture interventions to promote physical activity in the general population (Forberger *et al.*, 2019)	International Journal of Behavioral Nutrition and Physical Activity	56

Subject Areas

The results on the subject areas of publications are displayed in Table 3, indicating that the majority of studies (N=81) pertain to the field of medicine, which is unsurprising given the focus on physical activity in the health and medical sectors. This reflects the recognition of physical activity as a crucial component of public health promotion, with a strong emphasis on understanding its impact on physiological health outcomes. Moreover, in recent years, there has been a growing tendency toward the use of nudges in computer-related domains, specifically after the introduction of digital nudges by Weinmann *et al.* (2016). Nudges are interventions that have been increasingly used in a variety of domains, including digital environments, to encourage physical activity through smartphone apps, wearable devices, and gamification strategies to promote physical activity and improve public health outcomes.

Table 3. Documents categorized by subject area

Scopus Categories	Number of Publications	Percentage of Total Publications (%)
Medicine	81	39.3%
Computer Science	22	10.7%
Social Sciences	20	9.7%
Psychology	11	5.3%
Engineering	9	4.4%
Health Professions	9	4.4%
Nursing	9	4.4%
Environmental Science	8	3.9%
Biochemistry, Genetics and Molecular Biology	6	2.9%
Business, Management and Accounting	6	2.9%
Other areas	25	12.1%

The social sciences group, on the other hand, has paid less attention to the use of nudges in promoting physical exercise, despite the importance of sedentary behavior as a social issue. Inactivity and insufficient physical activity are identified as the fourth greatest cause of mortality worldwide (WHO, 2022c), and addressing this issue necessitates a multidisciplinary strategy that includes social, environmental, and policy aspects. Sociologists, psychologists, and public health researchers play an important role in studying the social determinants of physical activity behavior, which includes social norms, cultural influences, social support, and socioeconomic disparities. By investigating the social context of physical activity, researchers can learn how social, environmental, and policy factors influence physical activity behavior, as well as how nudge interventions can be designed to encourage physical activity across varied populations. This could include researching the effects of urban planning and the built environment on physical activity behavior, investigating the role of social networks and social support in influencing physical activity, and assessing the efficacy of policy interventions in promoting physical activity at the population level. Such studies can contribute to the development of evidence-based nudge interventions and policies that effectively promote physical activity as a social norm while improving public health outcomes.

Moreover, an additional nine research domains, accounting for 11.8% of the publications, merit attention but are not reported individually in Figure 2 and Table 3. These include; agricultural and biological sciences (N=5); neuroscience (N=5); economics, econometrics, and finance (N=4); arts

and humanities (N=3); decision sciences (N=3); mathematics (N=2); energy (N=1); multidisciplinary (N=1); and physics and astronomy (N=1).

The paucity of publications concerning nudges and physical activity within the economic domain is of notable concern. Thaler and Sunstein introduced the concept of nudges rooted in behavioral economics, which is an area that economic researchers should pay more attention to, particularly regarding physical activity. Sedentary behavior and physical inactivity entail significant costs for a society, emphasizing the necessity for enhanced exploration within economic paradigms. Similarly, scant attention has been given to related publications within the psychology domain, notwithstanding the elevated prevalence of mental health issues among overweight and obese individuals (Jones-Corneille *et al.*, 2012; Kalarchian *et al.*, 2007; Legenbauer *et al.*, 2009; Mitchell *et al.*, 2012; Rosenberger *et al.*, 2006). Psychologists, who specialize in studying the mind and its influence on behavior, have an opportunity to contribute valuable insights to society through research on increasing physical activity and mobility using nudge interventions, especially in populations with mental health challenges.

One critical highlight of the current research landscape is the limited number of studies conducted within the decision sciences and neuroscience domains. Despite decision-making and neuroscience being fundamental areas of study in human health behavior, only 5 and 3 studies, respectively, were identified in each group. Researchers can leverage insights from decision sciences and neuroscience to design nudge interventions that effectively motivate individuals to engage in regular physical activity. These interventions can target cognitive biases, emotional responses, and social influences that underpin decision-making and behavior, thereby potentially catalyzing transformative shifts in health behaviors and outcomes.

Journal Distribution

The data show that documents on nudges and physical activity are published in a wide range of sources, indicating significant development in the field. A total of 119 documents were screened and selected from 80 different sources. Due to the relatively new field, commenting on specific journals beyond the top ones might be premature. However, the top 5 most productive journals, as reported in Table 4, are notable for their focus on health and medicine, which aligns with the functional application of nudge interventions in improving individual and public health.

A collection of studies published in the BMC Public Health Journal stands out as the most cited ones in the field, with the highest number of citations, including a remarkable 230 citations for an article written by Hollands *et al.* (2013). The American Journal of Health Promotion ranked second in terms of citations, and its most cited article is the study by Cotton and Patel (2019) with 69 citations. The attention given by the editors of these journals to publish research on nudges and physical activity, especially since 2018 can serve as encouragement for researchers to pursue studies in this area. Almost all the listed journals have the potential to consider this research field, and every researcher can consider these journals as a resource to search for literature on nudges and physical activity and publish their studies. The total number of other sources is listed in the last row, which includes 59 journals and conferences not reported separately in Table 4 to avoid overwhelming information.

Table 4. Top 5 most productive journals

Journal	Publications	Citation	AC
International Journal of Environmental Research and Public Health	5	20	4.00
American Journal of Health Promotion	4	112	28.00
BMC Public Health	4	283	70.75
British Medical Journal (BMJ Open)	4	26	6.50
Contemporary Clinical Trials	4	25	6.25
Other Sources	59	1360	23.05

Note: AC = average citations

As part of the comprehensive analysis, VOSviewer was utilized to generate Figure 3, which presents a journal co-citation network. To ensure robustness, the analyses included journals with a minimum of 20 citations, resulting in 36 journals organized into three clusters. These clusters are color-coded as red (13 journals), green (12 journals), and blue (11 journals). Each node in the cluster also represents a journal, with the node size indicating the number of citations, and the distance between nodes indicating their relatedness in terms of co-citation links. Closer nodes indicate stronger relatedness. Lines in the visualization represent the strongest co-citation links between journals (Van Eck & Waltman, 2022). The thickness of the lines connecting the nodes varies, indicating that the strength of co-citation links between journals varies.

The red cluster is the largest. This suggests that there is a group of journals that are highly influential in the field of nudges and physical activity research. The most influential journal in the red cluster is also the American Journal of Preventive Medicine with 101 citations, a total link strength of 1795, and an impact factor of 5.5 (2022). However, it is noteworthy that this journal has published only 1 article written by Martin *et al.* (2012), indicating the potential for further research.

The green and blue clusters are smaller. It suggests that there is a broader range of journals that publish research in this field, but these journals may be less influential or have a specific focus. In the green cluster, the Journal of the American Medical Association is also prominent with 101 citations, 1366 total link strengths, and an impact factor of 120.07 (2022). In the blue cluster, the International Journal of Behavioral Nutrition and Physical Activity had 67 citations, 1109 total link strengths, and an impact factor of 8.7 (2022).

It is important to note that all journals in the three mentioned clusters are related to public health, but have published a limited number of articles on nudges and physical activity. Nevertheless, they can serve as valuable resources for researchers seeking appropriate journals to publish their research and cite relevant articles to enhance the scholarly impact of their work.

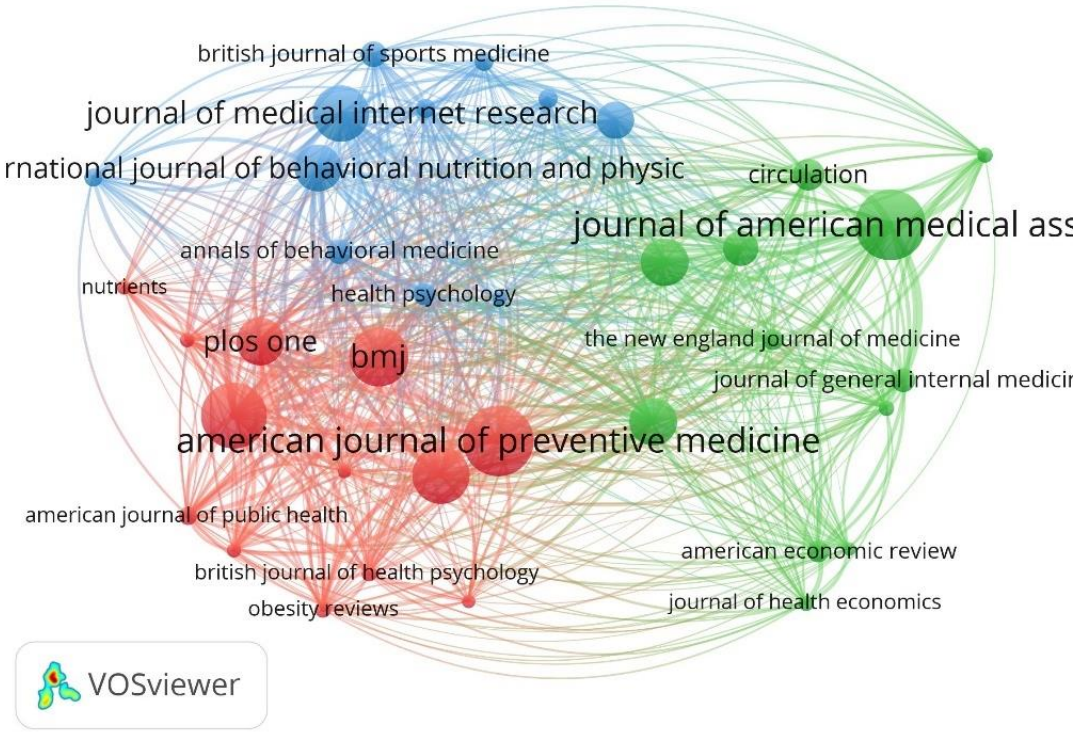

Figure 3. Journal co-citation network visualization

Country Distribution

Figure 4 highlights the distribution of documents by country, with a total of 119 publications across 30 countries. The United States led with 37.81% (N=45) of the total, followed by the Netherlands, the United Kingdom, and Germany with 17 (14.28%), 16 (13.44%), and 15 (12.60%) publications,

respectively. There were fewer than 10 studies each from other countries. This suggests that researchers from the US and several European countries have shown more interest in this research area. Because these regions might have a longer history and stronger infrastructure for research in health-related field, potentially leading to a head start in exploring new areas like nudges and physical activity. The presence of well-stablished funding mechanisms and research grants in these regions might also play a role in supporting research initiatives in this field. Notably, researchers from Asian countries have been less involved but could benefit from knowledge exchange with their counterparts from other countries and contribute to the advancement of this research area.

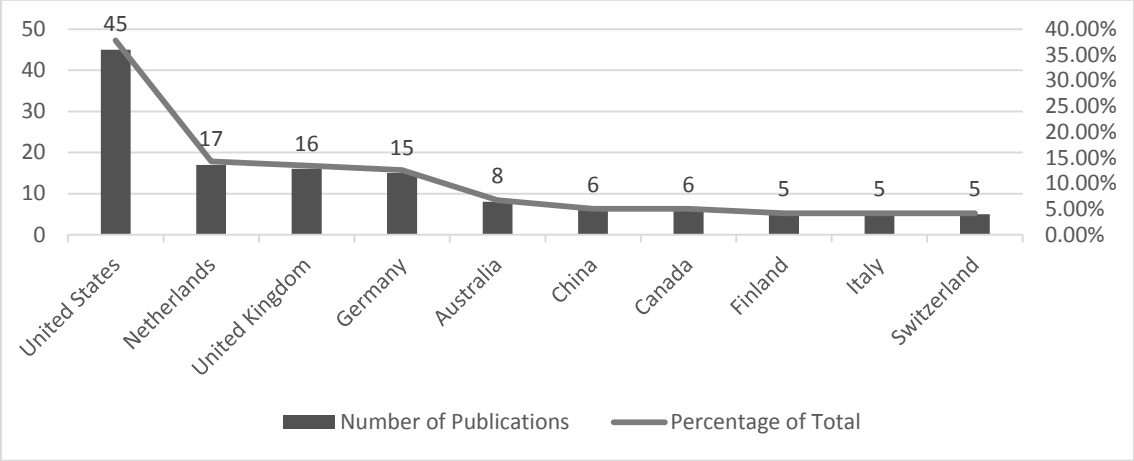

Figure 4. Distribution of documents by country

Figure 5 presents a network visualization of countries based on bibliographic coupling, which measures cooperation among countries through shared references (Van Eck & Waltman, 2022). In VOSviewer, the minimum number of documents for a country and the minimum number of citations for a country were set to 1. A total of 27 countries were analyzed, resulting in five distinct clusters: a red cluster with 8 countries, a green cluster with 7 countries, a blue cluster with 5 countries, a yellow cluster with 4 countries, and a purple cluster with 3 countries.

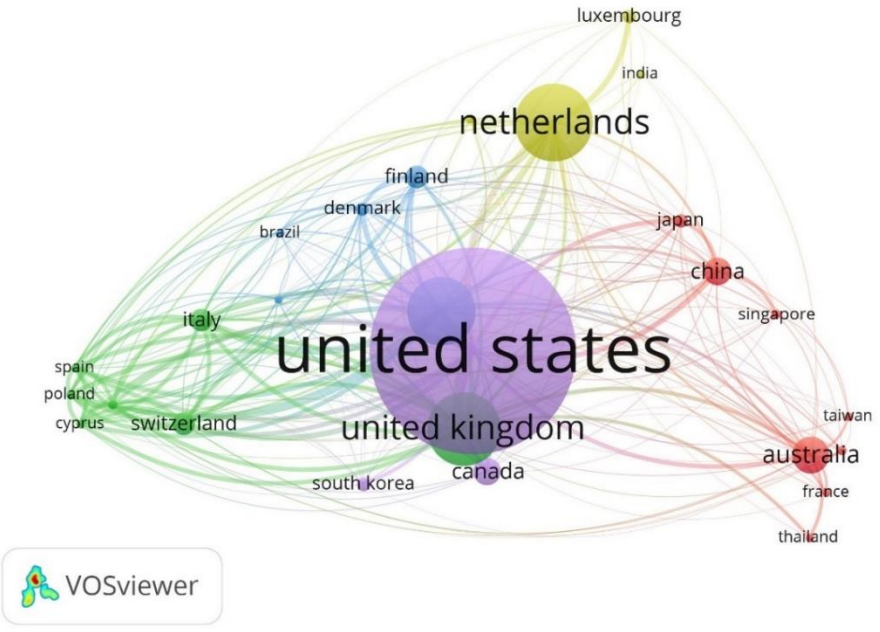

Figure 5. Visualization of the bibliographic coupling network of countries

One of the most notable clusters is the purple cluster, which is prominent with the United States with 735 citations and 2807 total link strengths. This country is at the forefront of researching and implementing nudges in various areas, including physical activity. The pioneering authors of Nudge, Thaler and Sunstein, are American researchers. Notably, the United States has also been one of the pioneers in successfully using nudges in policy administration, as highlighted by the National Science and Technology Council (2015). Alongside the United States, Canada also holds a significant position in this cluster with 29 citations and 384 total link strengths, having taken the initial steps in this research field.

In the green cluster, the United Kingdom with 426 citations and 1742 total link strengths is among the most influential regions in research on nudges and physical activity. Other European countries in the blue cluster, such as Germany with 232 citations and 2476 total link strengths, Finland with 37 citations and 532 total link strengths, and Denmark with 67 citations and 710 total link strengths are among the most influential in research on nudges and physical activity. The Netherlands in the yellow cluster is another European region with 293 citations and 1211 total link strengths. These European countries, similar to the United States, have a strong research background that enables them to conduct research effectively. However, despite the substantial research conducted in the United States and Europe, there is still untapped potential for further research in this field.

Australia and China are part of the red cluster, with total link strengths below 1000. While their contributions are noteworthy, the relatively lower link strengths suggest room for expansion and collaboration to unlock further research potential in these regions.

Figure 6 presents an overlay visualization of countries that have recently conducted research on nudges and physical activity. By default, relevant active research started in 2018. The United Kingdom has been a pioneer in these studies since 2018, followed by other countries such as Brazil, Romania, and France. By moving toward 2019, the Netherlands and Denmark were placed. The United States, Switzerland, Australia, Canada, Finland, and South Korea were also involved in this research field from 2019 to 2021. In recent years, there has been an increase in research in countries such as China, Japan, Greece, Luxembourg, and India. Consequently, developed countries generally play a larger role in these studies, as promoting physical activity through low-cost policies such as nudge tools aligns with their public health objectives. Asian countries have also shown interest in such studies, and it is predicted that more research will be conducted by researchers from these countries in the future. However, the extent of research in any scientific field depends on the research background and budget of different countries.

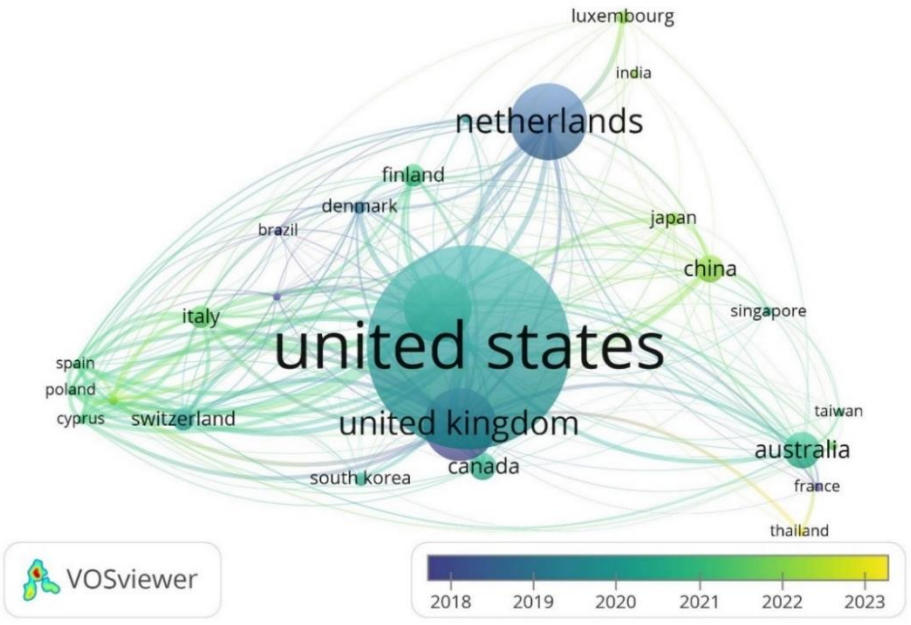

Figure 6. Overlay visualization of the country analysis

Author Distribution

Figure 7 and Table 5 present the most productive authors in the field of nudges and physical activity, based on their publication and citation records. The list was filtered to include authors with a minimum of 3 publications, resulting in 10 authors. Overall, 157 authors contributed to the conduct of 119 studies. Notably, Mitesh S. Patel, as a behavioral scientist, ranked at the top with 9 articles and a total of 382 citations. In the last 20 years, more than one-quarter of his studies have been dedicated to "Nudges, Behavioral Economics, Paternalism, Weight Reduction and Control Programs, and Exercise." Dylan S. Small and Victoria Hilbert are ranked second and third with 5 and 4 articles, respectively. Dylan S. Small, as a data scientist, has also contributed to behavioral issues. Victoria Hilbert, as the clerk of the Nudge Unit at the University of Pennsylvania, has studied issues similar to those of Mitesh S. Patel from 2016 to 2021. As it is clear from the table, others contributed to less than 4 studies on nudges and physical activity.

In terms of the H-index, Kevin G. Volpp has the highest H-index of 62. He is the founding director of the Center for Health Incentives and Behavioral Economics (CHIBE) and he has been contributing to nudge-related research. Based on the findings of the top authors, researchers may consider collaborating with these authors based on their backgrounds and publications in the field of nudges and physical activity.

Table 5. Top 5 authors according to the number of studies and citations

Author	Number of Documents	Citation	H-index
Mitesh S. Patel	9	382	37
Dylan S. Small	5	164	49
Victoria Hilbert	4	73	11
Pilvikki Absetz	3	37	29
Sara Forberger	3	73	11
Carine Lallemand	3	10	13
Charles A.L. Rareshide	3	166	16
Kevin G. Volpp	3	140	62
Steven B. Vos	3	7	23
Jingsan Zhu	3	142	33

A co-authorship analysis was conducted to explore collaboration patterns among authors, and the findings are presented in Figure 7. A total of 63 authors were considered, but 51 were found to be unconnected. Therefore, the analysis involved 12 other writers, each with at least 2 papers and citations. Two clusters were identified: the red cluster, consisting of 7 authors, and the green cluster, consisting of 5 authors. Mitesh S. Patel**,** Dylan S. Small**,** and Victoria Hilbert were the most cited researchers in the green cluster**.** Charles A.L. Rareshide is also a key member of the red cluster.

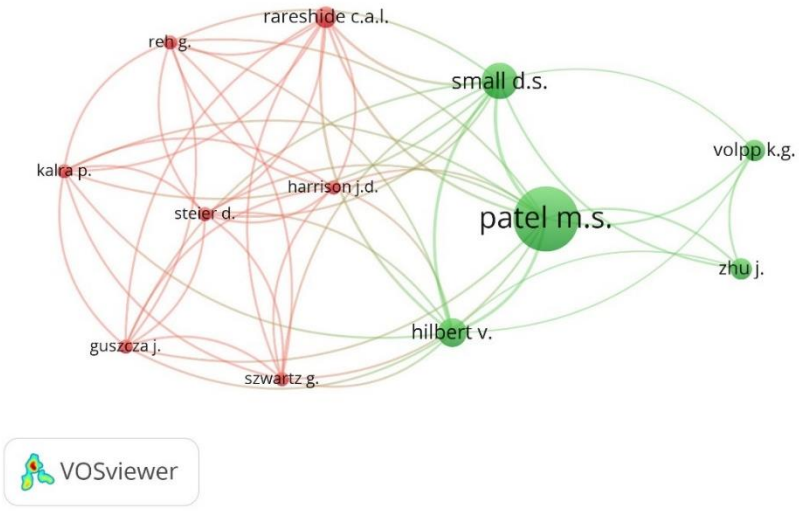

Figure 7. Network visualization for co-authorship analysis

Keywords Co-Occurrence Analysis

The analysis identified the main terms associated with the research field using a keyword co-occurrence network, as shown in Figure 8. In this analysis, each node represents a keyword, and the size of the node reflects its frequency in publications. A shorter distance between two nodes indicates a stronger relationship between them (Jiménez-García *et al.*, 2020). A minimum of 5 occurrences was set for each keyword, resulting in 96 keywords out of 1194 forming four clusters: red (N=38), green (N=21), blue (N=21), and yellow (N=16). Notably, the keyword "Behavior" and its derivatives appeared in both British and American writings, with only spelling differences.

The red cluster, being the largest, represents the central theme of research field. It highlights the following key concepts: the presence of "Nudge," "Choice Architecture," and "Behavioural Economics" keywords emphasizes the core focus of nudges, a type of intervention that influences behavior change through subtle cues or environmental design. The cluster also concludes the most frequently occurring keyword, means "Physical Activity"; this aligns with the overall goal of promoting healthy behaviors and improving public health. Following, keywords like" Behavior," "Behavior(ur) Change," "Behavioral Research," and "Public Health" situate the research within the broader context of understanding and influencing health behaviors at a population level. Additional relevant terms like "Health Behavior," "Health Promotion," and "Decision-Making" suggest a focus on understanding how individuals make choices related to physical activity and how nudges can influence these decisions.

Moreover, "Workplace" is another term in this cluster. Indeed, in countries such as the United States, more than 80% of jobs are low-mobility (Gremaud *et al.*, 2018). As a result, the workforce is regarded as a sensitive group to inactivity and sedentary behavior, and promoting physical activity based on scientific research is a vital topic for societies.

The green cluster highlights demographic variables including "Female," "Male," "Middle-aged," "Adult," and "Young Adult" as significant focal points. This focus demonstrates inadequate physical activity levels among different demographic groups (WHO, 2022a). Given the recognized dangers linked with sedentary lifestyles among them, researchers have particularly dedicated their efforts to addressing the health requirements of these populations. Behavioral Economics, as one of the main keywords in this study, significantly occurred in this cluster, indicating an increasing acknowledgment of how behavioral factors and health outcomes interact. In this cluster, terms such as "Body mass," "Obesity," and "Overweight" also draw attention to the health consequences of sedentary lifestyles. The theme coherence in the green cluster demonstrates a comprehensive approach to comprehending and dealing with the various factors influencing physical activity behavior. Researchers have attempted to develop comprehensive strategies for public health by combining demographic factors, behavioral economics concepts, and health-related results to appeal to various communities.

The blue cluster encompasses the keyword "Motivation". It highlights the importance of factors that motivate people to engage in physical activity. this knowledge is crucial for designing effective nudges. Therma like "Activity Tracker," "Fitness Trackers," and "Step Count," indicate the use of wearable technology to monitor physical activity levels. This data can be used for feedback, goal setting, and potentially as a nudge itself (e.g., social comparison with other's step count). The presence of "Gamification" in this cluster suggests researchers are exploring how game elements such as points, levels, badges, leaderboards, challenges, and rewards to make exercise routines enjoyable and rewarding (Miller *et al.*, 2016). With advancing technology and evolving human behavior, gamification holds immense potential to revolutionize health promotion efforts and contribute to global well-being (Seaborn & Fels, 2015).

The yellow cluster shows the growing role of technology in health management. The term "Mhealth[2]" indicates the use of mobile devices and applications to deliver nudge interventions and support physical activity. Following, "Mobile Application(s)" indicates specific mobile apps designed for physical activity promotion, have been explored by researchers. These apps could offer features like personalized exercise routines, progress tracking, and social interaction to enhance

[2] Mobile Health

motivation. "Telemedicine" and "Telehealth" also suggest the possibility of remote consultation with healthcare professionals who can provide guidance and support for physical activity programs.

In conclusion, the findings can guide researchers in selecting appropriate keywords to enrich their research literature and contribute to addressing the public health issue of physical inactivity and sedentary behavior, especially among vulnerable populations, by focusing on the nudge approach.

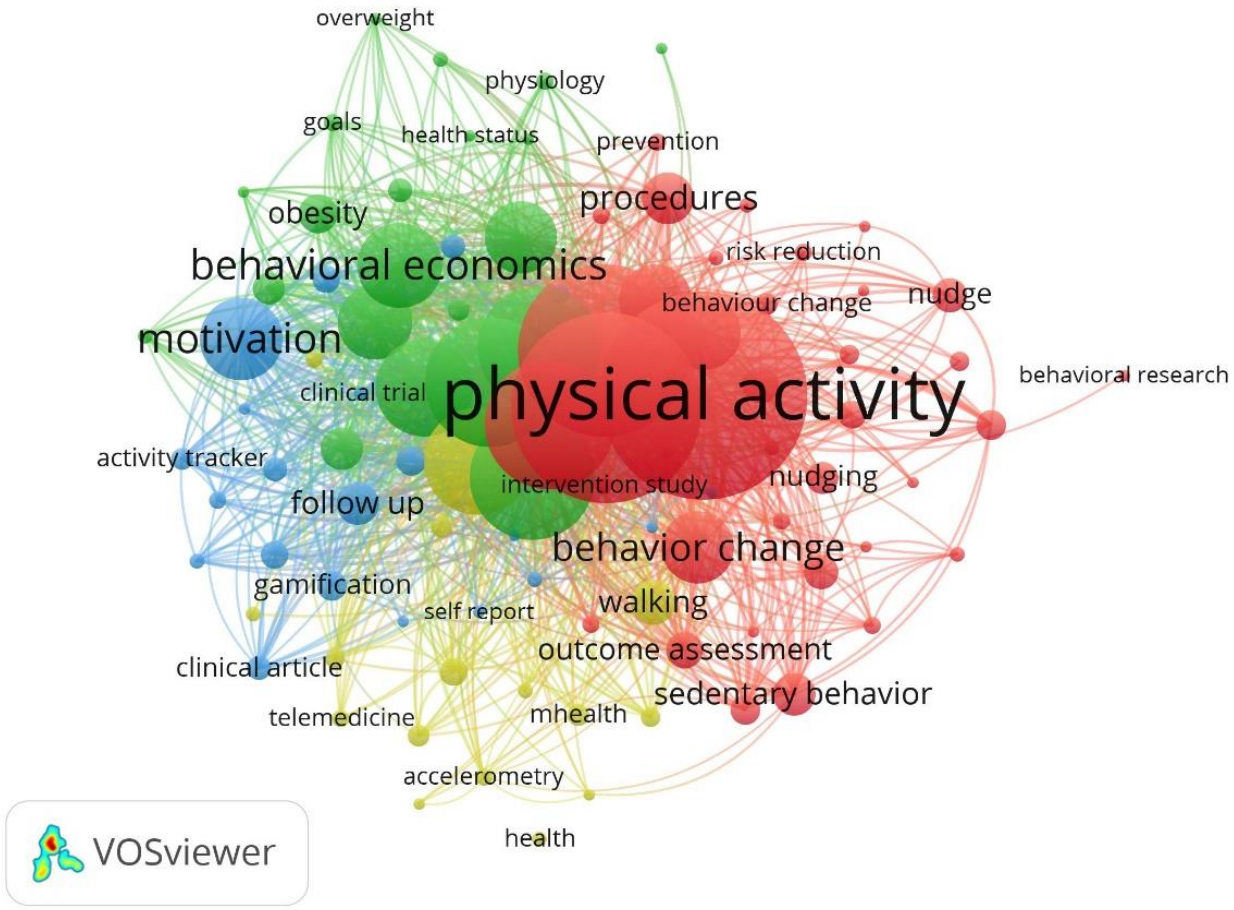

Figure 8. Network visualization of keyword co-occurrence analysis

The overlay visualization of keywords in Figure 9 reveals the evolving trends in research focus over the last six years. In 2018, health-oriented terms dominated the landscape, with keywords like "Health Behavior," "Obesity," "Psychology," "Diet," and "Overweight" appearing prominently. Notably, the occurrence "Diet" and "Obesity" alongside the increasing interest in the nudge approach also indicates a growing emphasis on multidisciplinary approaches to nudge-related research, encompassing both physical activity and nutrition (See e.g. Boonmanunt *et al.*, 2023; Kattelmann *et al.*, 2014; Laiou *et al.*, 2021; Papandreou *et al.*, 2023; Park & Kim, 2022; Rantala *et al.*, 2021; Stuber *et al.*, 2020).

In 2019, the emphasis shifted toward "Physical Activity" with a focus on different demographics like "Female," "Male," and "Adult." Following this, research interest grew in using "Randomized Controlled Trials" to rigorously evaluate the effectiveness of nudges. In 2020, researchers controlled and promoted "Clinical Studies." By 2021, the focus expanded to address "Sedentary Behavior," "Sedentary Lifestyle," and "Choice Architecture" as key areas of interest. Additionally, this period saw a significant interest in the number of "Review Papers," indicating that researchers aimed to achieve a deep understanding of the research field through this type of studies. Finally, the years 2021 to 2023 witnessed a surge in research exploring the potential of technology-based tools such as "Mhealth" and "Telehealth" for promoting physical activity.

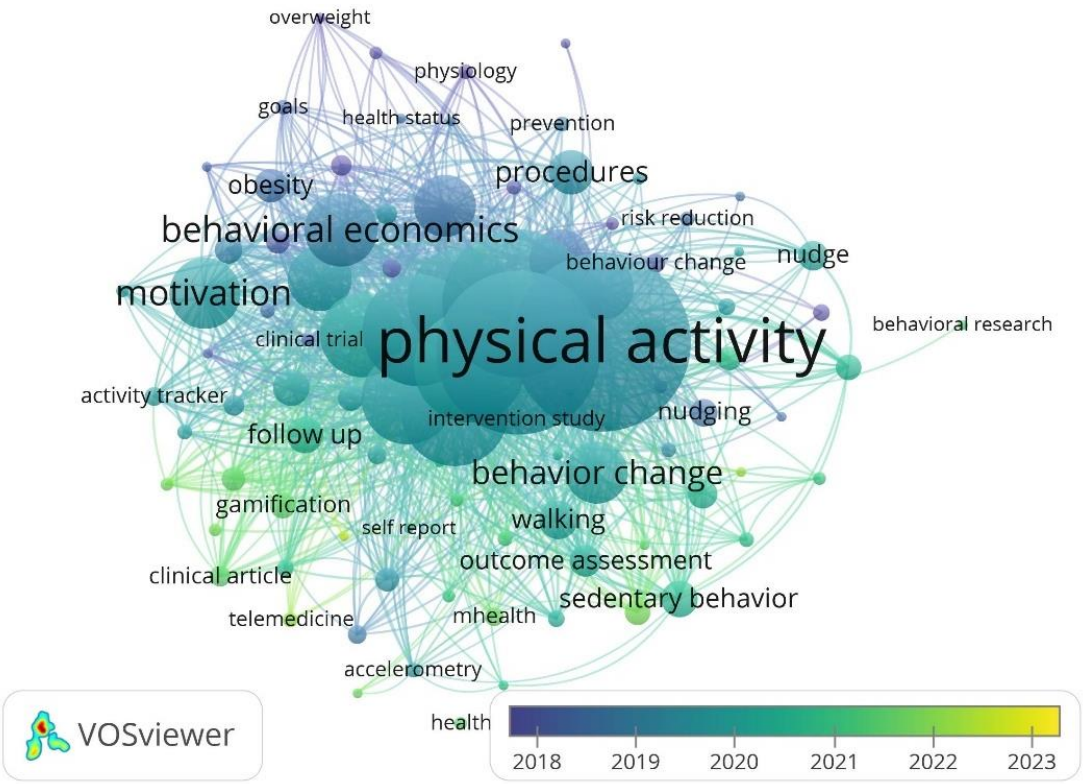

Figure 9. Overlay visualization of keyword co-occurrence analysis

Figure 10 provides insights into the depth of research in the field of nudges and physical activity. The density visualization reveals that keywords such as "Physical Activity," "Adult," "Health Behavior," "Behavioral Economics," and "Motivation" have been the primary focus of researchers, as evident from the closer proximity to yellow in the color spectrum. On the other hand, other keywords have a lower density, indicating that research on nudges and physical activity based on these terms is a relatively new and promising topic that researchers can further explore them in future studies, as reflected by the closer proximity to blue in the color spectrum.

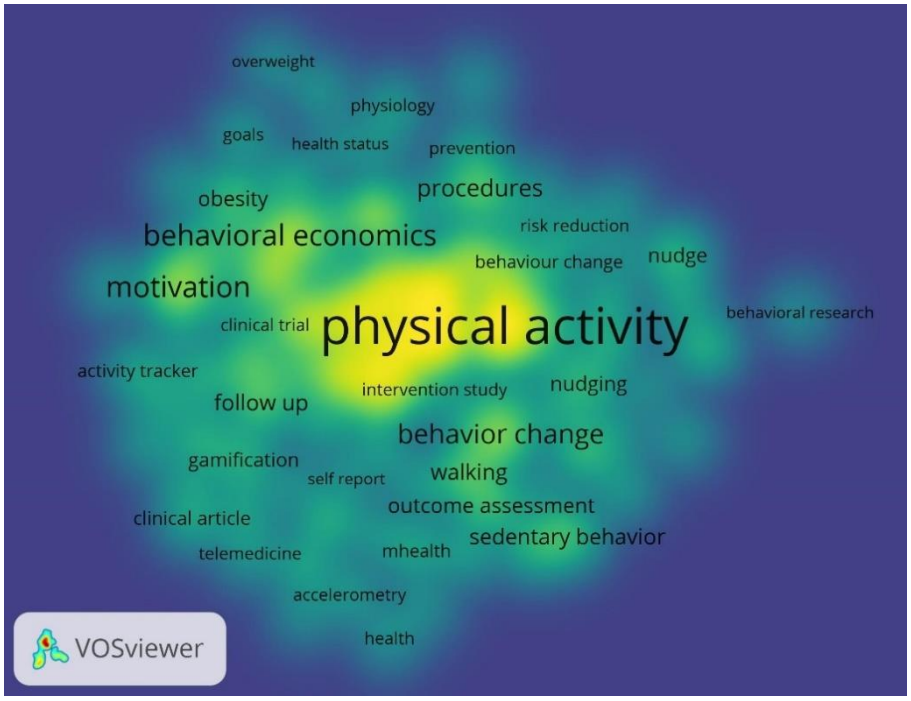

Figure 10. Density visualization of keyword co-occurrence analysis

Discussion and Conclusion

The growing interest in nudges as a tool for promoting healthy behaviors has spurred research across various fields, including physical activity. This study aimed to provide a comprehensive overview of this research domain by employing bibliometric approach with VOSviewer and analyzing publications on nudges and physical activity in the Scopus database. The analysis offers valuable insights into the development and trends in this area.

The findings highlight several key insights. First, the interest in nudges and physical activity has grown significantly since the introduction of the nudge concept by Thaler and Sunstein in 2008. Although, no studies were identified in 2008, the number of publications has steadily increased over the years, particularly after 2018. This trend indicates a rising acknowledgment of the potential of nudges to enhance physical activity and improve public health. The relatively modest number of publications in the past 15 years (N=119) also suggests that research in this area is still in its early stages, indicating opportunities for future exploration.

In terms of publication types, most published studies in this field are articles (N=81), followed by conference papers and reviews, reflecting a strong focus on original research and scholarly analysis within the domain. Geographically, the United States, Netherlands, United Kingdom, and Germany are leading the research efforts in this domain. Specifically, a significant portion of the studies (N=45) was conducted by American researchers, followed by research from European countries (N=48). This dominance by researchers from developed countries may be attributed established research infrastructure and the origin of the nudge theory.

The prominence of medicine-related studies underscores the strong link between physical activity and public health outcomes. Influential authors in the field include Mitesh S. Patel, Dylan S. Small, and Victoria Hilbert, whose work has significantly shaped the research landscape. The limited number of key contributors suggests that the field is still relatively new, offering ample opportunities for emerging researchers to make impactful contributions. Furthermore, some researchers have begun exploring the application of nudges in both nutrition and physical activity, demonstrating an interdisciplinary approach to promoting healthier lifestyles. These interdisciplinary efforts open promising avenues for future research to better understand the broad impact of nudges on health behaviors.

Keywords such as nudges, choice architecture, behavioral economics, physical activity, and health behavior are the central themes in the research field. The frequent use of these terms reflects the focus on health behavior and the choice architecture approach inherent in nudge theory. Additionally, the presence of keywords related to technology and motivation suggests a growing interest in the use of digital tools and the importance of understanding motivational factors in influencing physical activity. Visualizing these keywords revealed dominant research themes and disciplinary clusters, offering insights into the research current trends and future directions in this area.

While the present study sheds light on the dominant research themes and clusters related to nudges and physical activity, it is important to acknowledge the study's limitations. One notable limitation is that the authors had to use the Scopus database only, due to Iranian researchers' limited access to other databases because of sanctions and other political issues. Thus, future research on this topic would benefit from examining other databases, such as Web of Science, PubMed, or Google Scholar, to ensure doing a more comprehensive literature review. Another limitation is that only English-language studies were included in the analysis, which may have led to language bias. Future research can consider studies in other languages, especially those published in non-English speaking countries, to avoid language and cultural bias. By addressing these limitations and pursuing these suggested research avenues for further exploration, scholars can contribute to a more comprehensive and robust understanding of nudges and their potential to promote physical activity and overall well-being.

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Author Contributions

All authors have contributed in conducting this study.

Conflicts of Interest

The authors declare no conflict of interest.

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