

Bibliometric Analysis of Revolutionizing Physical Activity: Challenges and Potentials of Emerging Technologies

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Abstract. New technologies such as artificial intelligence (AI), virtual reality (VR), wearable devices, and digital applications are changing the way physical activity is understood, promoted, and practiced. This study was conducted with the aim of assessing the intellectual structure and research trends on the physical activity revolution, especially in analyzing the challenges and potentials of using technologies. The study analyzed publication trends, citation patterns, distribution geography, high-impact journals, and author collaboration analysis. Data were sourced from the Scopus database covering the time span of 2010 to 2024. Network visualization maps were used to reveal collaborative networks among researchers to identify subfields and emerging knowledge gaps. The results found that keywords such as “physical activity”, “health promotion”, and “sports” also indicate that health research has become very popular. Furthermore, the inclusion of modern technologies such as “artificial intelligence” and “virtual reality” show how health research has changed. These findings provide valuable insights into the evolution of research in this field, highlighting influential studies and emerging trends that shape the future of physical activity and health promotion. This analysis serves as a resource for researchers, policy makers, and practitioners to align their strategies with evidence-based practices and encourage interdisciplinary collaboration in leveraging technology to improve physical activity outcomes.

Keywords: Emerging Technologies, Physical Activity, Digital Health.

1. Introduction

Physical activity is a fundamental component of a healthy lifestyle, with significant benefits for physical, mental, and social well-being [1]. It is a proven strategy for preventing non-communicable diseases, including cardiovascular conditions, diabetes, and certain cancers, while also improving mental health, cognitive function, and overall quality of life [2, 3]. Despite these well-documented benefits, global levels of physical activity remain alarmingly

low, with sedentary behaviors increasingly prevalent due to urbanization, digitalization, and changing work environments [4]. This decline has spurred the need for innovative solutions to promote active lifestyles and address the barriers that prevent individuals from engaging in regular physical activity.

In recent years, emerging technologies have opened new frontiers for transforming the way people approach physical activity. Innovations such as artificial intelligence (AI) [5], virtual reality (VR) (Zhou, 2020) [6], wearable fitness trackers [7], and mobile health (mHealth) applications are redefining the landscape of physical activity promotion [8]. These technologies enable real-time monitoring of physical performance, offer personalized training regimens, and utilize gamification to enhance motivation and user engagement. For example, AI-powered fitness platforms provide customized workout plans based on user data, while VR environments simulate immersive exercise experiences that cater to varying fitness levels and preferences.

However, while these advancements are promising, they also bring significant challenges. Data privacy concerns, unequal access to technology due to socioeconomic disparities, and the need for sustained user engagement remain critical barriers to widespread adoption. Moreover, the effectiveness of these technologies in achieving long-term behavioral change and improving health outcomes requires further empirical validation. The rapid pace of technological development also presents a challenge for integrating these innovations into existing public health frameworks and regulatory systems.

This study investigates the role of emerging technologies in revolutionizing physical activity, with a specific focus on their potentials and associated challenges. Employing a bibliometric analysis, it seeks to provide a comprehensive overview of the research landscape, identifying trends, influential studies, and key areas of collaboration. By analyzing publication patterns, citation networks, and thematic clusters, this research aims to highlight the most impactful contributions and uncover gaps that need to be addressed to optimize the integration of technology in promoting physical activity.

Ultimately, this study aspires to contribute to the growing body of knowledge at the intersection of technology and health promotion. The findings are intended to inform policymakers, researchers, and practitioners on the effective utilization of these innovations, ensuring equitable access and maximizing their potential for fostering active, healthy lifestyles across diverse populations. By addressing the dual dimensions of opportunity and challenge, this research emphasizes the critical importance of interdisciplinary collaboration in shaping the future of physical activity and health promotion in a technology-driven world.

2. Method

This study employs a bibliometric analysis to explore the research landscape surrounding the role of emerging technologies in revolutionizing physical activity. Bibliometric analysis is a quantitative method used to assess the development, structure, and trends within a specific field of study through the analysis of scientific publications, citations, and collaborative networks. The methodology for this research involves five steps that shows in Figure 1.

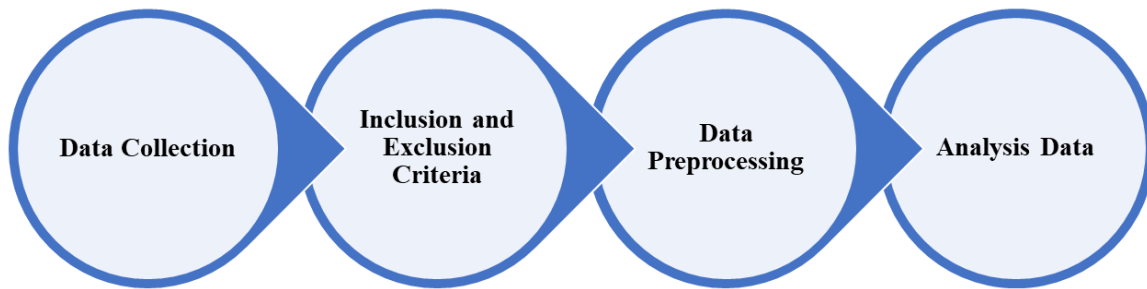


Figure 1. Research procedure.

2.1. Data Collection

The primary data for this analysis is sourced from established academic databases, including Scopus, which provide comprehensive coverage of high-impact publications. The search is conducted using a combination of relevant keywords, such as "physical activity," AND "emerging technologies," OR "wearable devices," OR "artificial intelligence," OR "virtual reality," AND "health promotion." The search is restricted to articles, conference proceedings, and reviews published in the last two decades to capture the evolution of this domain.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria for this review focus on publications that explore the application of technology in promoting, monitoring, or supporting physical activity. These studies must address challenges associated with such technologies or evaluate their effectiveness in enhancing physical activity outcomes. Conversely, the exclusion criteria eliminate studies that do not center on physical activity or those that exclusively examine traditional methods without integrating any technological components. This ensures that the analysis remains focused on the intersection of technology and physical activity.

3. Results and Discussion

3.1. Results

3.1.1. Descriptive Analysis

Figure 2 show the number of publications per year. The chart illustrates the annual trend in the number of documents published from 2010 to 2024, showing a general increase over the years with notable fluctuations. Between 2010 and 2013, the number of publications remained relatively low and stable, with minor peaks in 2011 and 2013. From 2014 to 2017, there was steady but modest growth, indicating consistent interest in the research area. A significant spike in publications occurred in 2018, marking a notable rise in research activity. However, between 2019 and 2022, the number of publications fluctuated but remained relatively stable, with no major upward or downward trends. The most dramatic change occurred from 2023 to 2024, where the number of publications surged sharply, with 2024 recording the highest output in the dataset. This overall trend suggests increasing research interest over time, with particularly rapid growth in recent years.

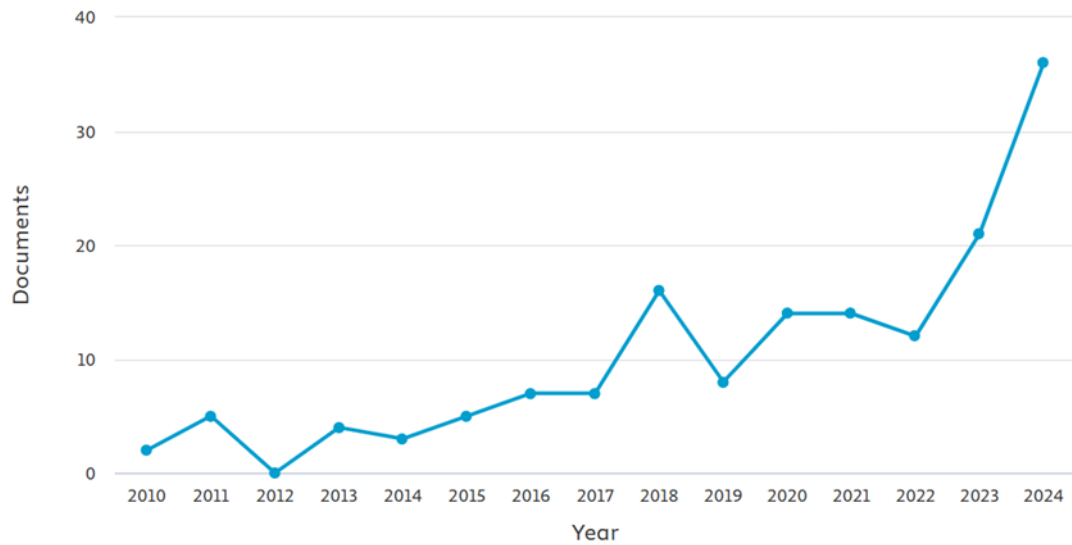


Figure 2. Number of publications per year.

Figure 3 shows the trend of document production from various journal sources during the period 2010 to 2024. The International Journal of Environmental Research and Public Health showed a significant increase, peaking in 2020, before declining but remaining stable until 2024. In contrast, the Journal of Diabetes Science and Technology experienced a consistent decline since 2011 until it was no longer detected in the following years, reflecting a decline in contributions to related research. Meanwhile, the Journal of Medical Internet Research began contributing in 2018 and maintained a stable publication rate until 2024, indicating a consistent commitment to this research topic. Studies in Health Technology and Informatics had a small but stable contribution throughout the period, with minimal fluctuations. On the other hand, the British Journal of Sports Medicine experienced a surge in publications in 2018, but its contribution decreased drastically after that and was no longer visible in the following years. These variations reflect the role of each journal in supporting the development of research in its field.

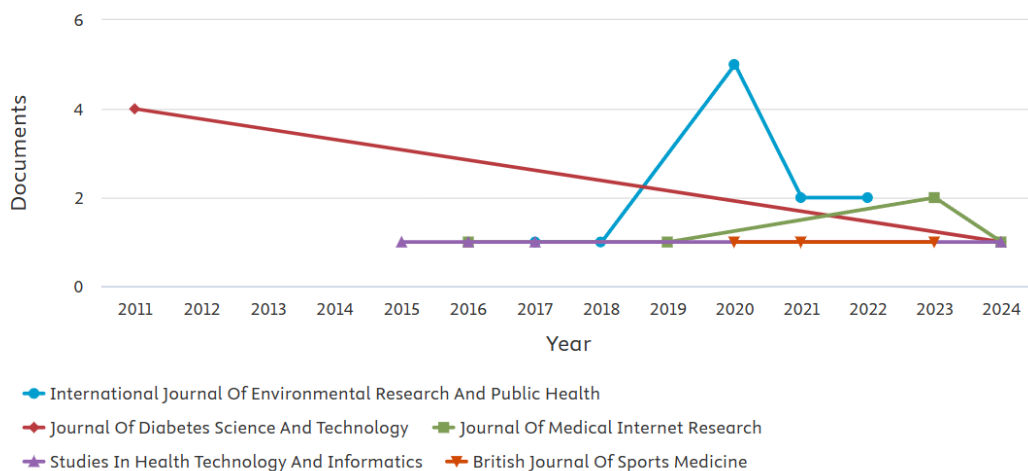


Figure 3. Sources' production over time.

Figure 4 shows the geographical distribution of publications. The data not only shows the geographical distribution of publications, but also provides insight into the contribution of research excellence in each country. The United States (USA), which leads with 318 publications, reflects its position as a global hub for research and development with a strong academic infrastructure, a large number of top universities and significant funding support. China, with 73 publications, shows rapid growth in research thanks to its massive investment in science and technology and its drive for global innovation. Australia, with 55 publications, stands out for its strengths in environmental, health and information technology research, supported by extensive international collaboration.

Countries such as South Korea (49 publications) demonstrate strengths in technology and innovation, particularly in health and electronics technology, while Canada (34 publications) has a reputation for multidisciplinary research with a focus on health and the environment. Spain (31 publications) and the United Kingdom (30 publications) continue to play a leading role in global research, with a focus on the social sciences, medicine and technology. Countries such as Italy (27), Brazil (26), and Netherlands (23) also have strengths in specific areas, such as health technology in Italy, biotechnology in Brazil, and collaborative approaches in the Netherlands that support innovation.

Countries with smaller contributions, such as Thailand (22), France (18), and Germany (17), nevertheless show strengths in specific areas, such as biodiversity, medical technology, and materials science. Although countries such as Indonesia, Philippines, and Venezuela have only recorded one publication each, this reflects an opportunity to further increase engagement and contribution to global research. The dominance of developed countries in this study also highlights the importance of technology transfer and international collaboration to encourage participation from developing countries.

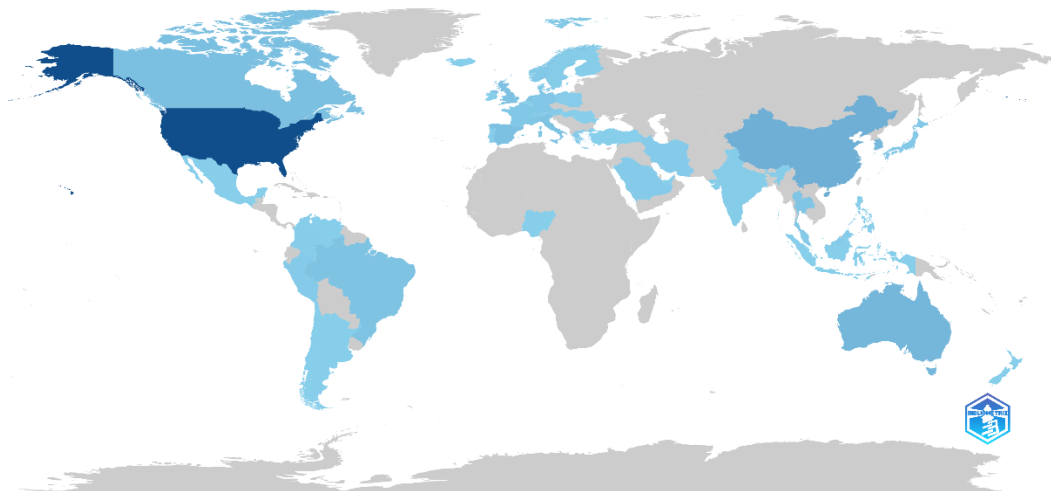


Figure 4. Geographical distribution of publications.

3.1.2. Citation analysis

Figure 5 shows a visualization of the bibliometric network connecting three main elements, namely CR (Citation References), AU (Authors), and DE (Keywords). This visualization provides an overview of the complex relationships between the main reference literature, the authors' contributions to a particular field, and the dominant research themes.

On the left, the most frequently cited references reflect the theoretical and methodological foundations of the research conducted. Some important references cover topics such as the use

of gamification in health promotion, mHealth (mobile health) applications, and physical activity guidelines to improve public health. The middle section shows the authors who contributed significantly, with some authors connected with many references and keywords. This shows their important role in supporting the development of certain themes, such as digital health, health promotion, and technology for monitoring physical activity.

On the right, keywords such as physical activity, health promotion, mhealth, digital health, wearable devices, and gamification are the most frequently appearing themes. These keywords reflect the main focus of the studies analyzed. The relationships between references, authors, and keywords illustrate the dynamics of scientific collaboration and the influence of certain themes in shaping the direction of research in this field. For example, themes such as mhealth and gamification appear to have strong connections with several key authors and references, indicating that these two topics are currently of major interest in contemporary research.

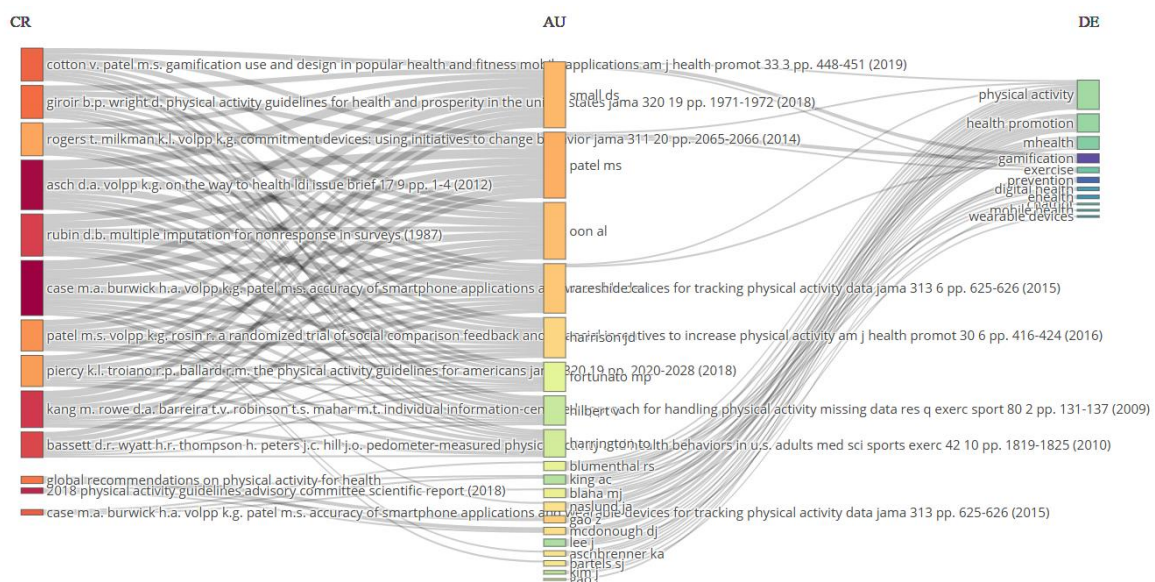


Figure 5. Three-field plot.

Table 1 shows the most citation article challenges and potentials of technology in revolutionizing physical activity in Scopus. **Table 1** reflects the progress of research in health technologies, particularly related to physical activity promotion and health improvement through digital technology-based interventions. **Table 1** reflects significant advances in health technology research over the past decade, with a primary focus on wearable devices, mHealth interventions, and virtual reality applications. These technologies not only facilitate health promotion and disease prevention but also open up opportunities for personalized healthcare. Future research can continue to explore the integration of advanced technologies to expand coverage and positive impact on the global population.

The most cited study is the study by Bickmore et al. (2013) with 226 citations, which highlights the effectiveness of automated exercise trainers for the elderly [9]. This shows the high interest and relevance in developing technological solutions to support the elderly population who require a tailored approach to promoting their health. The study by Xie et al. (2018), which examines the accuracy of wearable devices in tracking physical activity, also has a significant impact with 223 citations [10]. This confirms the important role of wearable devices as an increasingly reliable health monitoring tool. Another study by Martin et al. (2015)

on mHealth interventions to promote physical activity recorded 197 citations, underlining the potential of automation-based technologies to increase motivation for physical activity in various population groups [11].

In addition, the topic of using virtual reality and active games as tools to increase physical activity is also of high interest, as seen in the studies by Qian et al. (2020) and Foley & Maddison (2010) [15, 16]. Virtual reality is not only effective in supporting rehabilitation, but also provides an engaging experience to motivate physical activity. Meanwhile, electronic media-based studies, such as those conducted by Hieftje et al. (2013), highlight the role of media-based technology in influencing health behavior, especially in the younger generation [18]. Overall, these studies show an increasing use of digital technology for health promotion, whether through mHealth-based applications, wearable devices, or innovative approaches such as virtual reality. With many studies covering global regions, including developing countries as discussed by Müller et al. (2016), this research not only has local relevance but also makes an important contribution in the context of global health [12]. Future research can continue to explore new technologies to expand the positive impact on public health worldwide.

Table 1. The most citation article about challenges and potentials of technology in revolutionizing physical activity in Scopus.

Document Title	Year	Citations	Ref
A randomized controlled trial of an automated exercise coach for older adults	2013	226	Bickmore et al. (2013) [9]
Evaluating the validity of current mainstream wearable devices in fitness tracking under various physical activities: Comparative study	2018	223	Xie et al. (2018) [10]
mActive: A randomized clinical trial of an automated mHealth intervention for physical activity promotion	2015	197	Martin et al. (2015) [11]
The effectiveness of e- & mHealth interventions to promote physical activity and healthy diets in developing countries: A systematic review	2016	168	Müller et al. (2016) [12]
A Fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: A pilot study	2017	167	Mendoza et al. (2017) [13]
Mobile health devices as tools for worldwide cardiovascular risk reduction and disease management	2015	163	Piette et al. (2015) [14]
The effectiveness of virtual reality exercise on individual's physiological, psychological and rehabilitative outcomes: A systematic review	2020	157	Qian et al. (2020) [15]
Use of active video games to increase physical activity in children: A (virtual) reality?	2010	151	Foley and Maddison (2010) [16]
Using an electronic activity monitor system as an intervention modality: A systematic review	2015	144	Lewis et al. (2015) [17]
Electronic media-based health interventions promoting behavior change in youth: A systematic review	2013	140	Hieftje et al. (2013) [18]

3.1.3. Collaborative networks

Figure 6 shows the collaboration network among authors of related research, with node size and network density reflecting the level of contribution and connections between authors. This network provides insight into the structure of collaboration within a research community focused on a particular field.

The largest node in Figure 6 is Patel MS, who appears to have many connections to other authors, such as Hilbert and Agarwal AK, indicating that Patel MS is one of the most influential authors with extensive collaborations in this field. The red cluster where Patel MS is located is the densest, indicating intensive collaboration activity among this group of authors. In addition to the main cluster, there are several other small clusters that are separate, reflecting groups of authors with more limited collaborations. For example, Gao Z and McDonough DJ in the blue cluster, who are closely connected to each other but not connected to the larger group. Müller AM in the gray cluster appears to be an independent author with no connections to other authors in this network, indicating that their research may involve less cross-group collaboration [12].

Other clusters, such as the purple cluster containing Naslund JA, Schrenner KA, and Bartels SJ, indicate small groups that collaborate exclusively, while the green cluster with Blumenthal RS and Al Rifai M indicates more focused collaborations. The orange cluster with Al-Anazi S, Alawaji F, and Al-Omari A indicates regional or thematic groups that may be based on collaborations in specific fields or geographic regions. Overall, this network reflects that collaboration in research tends to be centered around a few key authors who have a large influence in the research network, such as Patel MS, who has built many relationships across groups. However, there are still several small, independent groups operating outside the main network, indicating diversity in research approaches and focus.

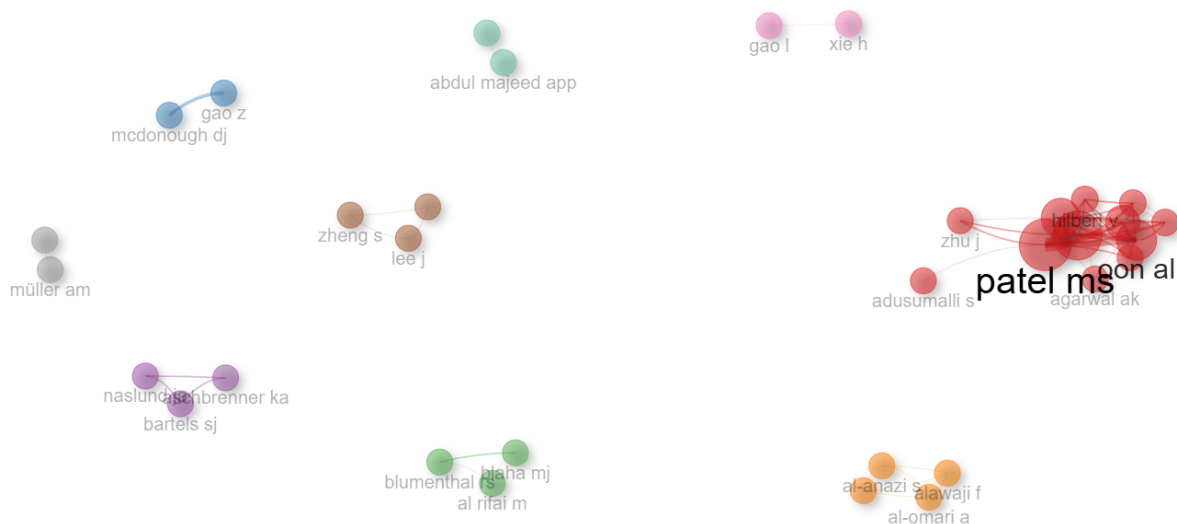


Figure 6. Collaborative author network visualization.

3.1.4. Keyword co-occurrence analysis

The visualization in Figure 7 provides insight into the most frequently occurring keywords in research related to physical activity and health promotion, as well as the thematic relationships between these keywords. The most dominant keyword is “physical activity” with 133 occurrences and a total relationship strength of 2,449, followed by “health promotion” (130 occurrences, 2,407 relationship strength), and “human” (125 occurrences, 2,475 relationship strength). Other keywords such as “exercise”, “article”, and “controlled study” also appear frequently, reflecting the main focus of research on physical activity, human health, and systematic research methods.

Figure 7 provides a very comprehensive overview of research trends in the field of physical activity and health promotion. Keywords such as “physical activity”, “health promotion”, and “exercise” indicate that this topic is a center of attention in the scientific literature. In addition, the involvement of modern technologies such as “artificial intelligence” and “virtual reality” reflect the transformation of health research towards integrating technology to improve health outcomes. These relationships also show cross-theme collaborations, such as the use of wearable devices, mobile applications, and artificial intelligence to promote health and encourage physical activity. Using network analysis, the identification of blue, red, green, and purple clusters helps clarify different research focuses. The clusters or groups in the network map indicate different research focuses. For example:

- (i). Blue cluster: Focuses on research involving demographic aspects such as "male", "female", "adult", and "aged", as well as methodological approaches such as "controlled study".
- (ii). Red cluster: Relates to advanced technologies such as "artificial intelligence", "telemedicine", and "internet", which are used in modern health research.
- (iii). Green cluster: Shows relationships with medical aspects such as "chronic disease", "patient monitoring", and "decision making".
- (iv). Purple cluster: Leads to lifestyle aspects and intervention tools, such as "mobile applications", "pedometers", and "sedentary lifestyle".
- (v). These clusters show a broad spectrum from demographic approaches to advanced technology applications and medical aspects, all of which contribute to a holistic understanding of how to effectively promote physical activity and health.

These insights are relevant not only to researchers, but also to health practitioners seeking to understand current trends in the use of technology to support evidence-based health interventions. The analysis also provides guidance for developing policies that can leverage emerging technologies to improve public health.

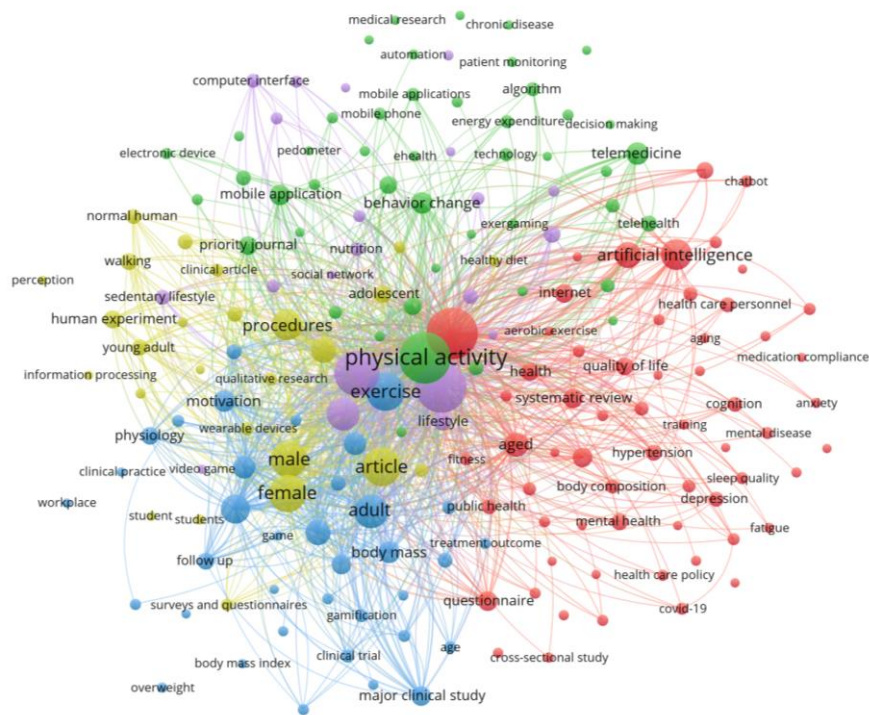


Figure 7. Network visualization of keyword co-occurrence analysis.

3.2. Discussion

New technologies have transformative potential in addressing traditional challenges associated with promoting physical activity [19]. These innovations offer personalized and adaptable solutions through AI-based platforms that design customized fitness plans, increasing user engagement and effectiveness. Gamification further enhances this engagement by incorporating fun and interactive elements, such as fitness games and virtual reality (VR) simulations, that make exercise more engaging [20]. Wearable devices add another layer of support by enabling real-time monitoring of vital metrics, including heart rate, step count, and calorie expenditure, providing users with actionable insights to guide their fitness journey. Additionally, mobile health apps and other digital tools are democratizing access to fitness guidance, allowing individuals in remote or underserved areas to access resources that were previously inaccessible [21, 22].

However, despite these opportunities, several barriers are hindering the full potential of new technologies in this area. One major challenge is data privacy and security; concerns about the misuse of sensitive health data often deter users from adopting these technologies. The digital divide also presents a significant barrier, as socioeconomic disparities limit access to advanced technologies, especially in low-income areas. Furthermore, sustained user engagement remains a critical issue, as many individuals discontinue using wellness technologies due to declining interest or lack of seamless integration into their daily routines. Device reliability, including issues such as accuracy, battery life, and compatibility, also impacts user satisfaction and trust. Finally, regulatory gaps – such as lack of standardization and oversight – pose risks to users and hinder the scalability of digital health solutions.

A critical examination of existing research reveals several gaps that need to be addressed to maximize the potential of these technologies. First, there is a lack of long-term studies

evaluating the sustained impact of new technologies on behavior change and health outcomes. Second, research often neglects vulnerable populations, including older adults, individuals with disabilities, and those from low-income backgrounds. Third, there is a lack of attention paid to the integration of these technologies within public health and clinical frameworks, limiting the ability of these technologies to have a broader systemic impact.

To address these challenges and address the identified research gaps, several strategic actions are needed. Inclusive research and design practices should prioritize the development of technologies that serve diverse populations, including those in low-resource settings. Additionally, leveraging insights from behavioral science can enhance the sustainability of engagement by creating interventions that motivate long-term use. Establishing a strong regulatory framework is also important to address data privacy concerns and ensure interoperability across devices and platforms. Furthermore, encouraging global collaboration between high- and low-income countries can facilitate the exchange of knowledge and resources, promoting equity in the adoption of these technologies.

Integrating emerging technologies into national health promotion strategies requires proactive engagement from policymakers, practitioners, educators, and researchers. Policymakers should prioritize aligning these technologies with broader health goals, ensuring their accessibility and ethical implementation. Practitioners can leverage these tools to deliver personalized interventions that drive greater engagement and effectiveness among users. Meanwhile, educators and researchers should adopt an interdisciplinary approach to address the complexities of technology adoption and its broader societal implications. By bridging research, design, and implementation gaps, emerging technologies can become powerful drivers of healthier, more active lifestyles across diverse populations.

4. Conclusion

Emerging technologies have the potential to redefine physical activity promotion by addressing challenges of accessibility, personalization, and engagement. However, realizing this potential requires addressing barriers such as data security, digital inequality, and long-term desires. This study highlights the importance of global collaboration, inclusive design, and strong policy frameworks in maximizing the impact of these innovations. The study found a very comprehensive overview of research trends in physical activity and health promotion, where the keywords “physical activity,” “health promotion,” and “exercise” show that this topic is at the center of attention in the scientific literature. Furthermore, the inclusion of modern technologies such as “artificial intelligence” and “virtual reality” reflects the transformation of health research towards integrating technology to improve health outcomes. By aligning technological advances with public health goals, these tools can contribute to promoting active and healthy lifestyles for diverse populations around the world.

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