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Trends and global power of research on physical activity, depression, and anxiety in adolescents and young adults: science mapping the literature

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ABSTRACT

To understand the pluralization and global power of research on physical activity (PA), depression, and anxiety in adolescents and young adults, a bibliometric analysis-based science mapping of publications in this field was conducted. Scopus was searched for peer-reviewed journal articles published from 2010 to 2022, which resulted in 2,668 records, of which more than half were published from 2020 onwards. Research and collaborations were concentrated in countries in the Global North. Research trends, based on keyword co-occurrence analysis, suggest: an apparent shift towards more PA research connected to sleep, and de-emphasis on research related to weight concerns; research addressing barriers to participation in PA; an increasing interest in the mental health of university students; and the differential effects of team and individual sports on anxiety and depression. Emerging research fronts focused on alternative therapies, new technologies, and impacts of COVID-19. The findings could guide avenues for future research and policy.

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Physical activity; youth; wellbeing; mental health; sport; bibliometric analysis

Introduction

To achieve the *United Nations Sustainable Development Goals (SDG)*, globally, researchers, policy-makers and educators must work in partnership by enhancing North–South, South–South and regional cooperation (Target 17.6; The Global Goals, *n.d.-b*). One of the areas for these partnerships is centred on prioritizing the good health and wellbeing of populations, including during adolescence and early adulthood (Target 3.4; The Global Goals, *n.d.-a*). Adolescence and early adulthood is a critical period for treating and preventing longer-term mental health issues (Essau et al., 2014), since 75 per cent of adult mental health disorders develop by age 24 (Jones, 2013). The main contributors to the global mental disorder burden are anxiety and depressive disorders (Santomauro et al., 2021), with the median age of onset being 17 years for anxiety disorders, and 30 years for depressive disorders (Solmi et al., 2022). Hence, researchers have focused on approaches to managing mental health and wellbeing through interventions, such as medication and cognitive behavioural therapy (CBT). However, these have shown variable levels of success in treating adolescent depression (Dunn & Weintraub, 2008), so interventions that go beyond pharmacological treatments and/or psychological therapies, sometimes referred to as ‘active ingredients’, are now being prioritized for combating anxiety and depression in young people (Sebastian et al., 2021; Wolpert et al., 2021).

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Physical activity (PA) – defined as ‘any bodily movement produced by skeletal muscles that requires energy expenditure’ (World Health Organization, 2024) – is one active ingredient that has been proposed (Sebastian et al., 2021). Recent meta-analyses have observed that PA can result in small to medium reductions in anxiety and depressive symptoms, while providing potential protective benefits against the future development of conditions (Carter et al., 2021; McDowell et al., 2019; Rebar et al., 2015; Wegner et al., 2020). Some evidence shows that PA interventions have equivalent effects to psychotherapy, and improved effects over antidepressant medications (Bailey et al., 2018). For example, Taranina et al. (2020) combined psychotherapy with physical exercise in adolescents, and found that it decreased their depression and anxiety levels by 2.27 and 2.23 times, respectively, compared with 1.7 and 1.78 times, respectively, for psychotherapy alone. Supervised group aerobic exercises of moderate to vigorous intensity are the most effective form of PA for reducing depression in young people (Bailey et al., 2018). Hsu et al. (2021) found that 6 to 12 weeks of up to 60 minutes of brisk-walking per week decreased adolescents’ depression and anxiety levels. Given these promising findings about the efficacy of PA, the World Health Organization (WHO) – which champions global efforts to promoting health through policymakers and practitioners – advocates PA for improving mental health in young people (World Health Organization, 2024).

Despite the global agenda of developing healthy nations, there may be some nations that are researching into the area of PA more heavily, and they are therefore shaping the global discourse in this space. For example, due to growing concerns around participation in PA by young people, many Western nations, including Australia, Canada, the United Kingdom (UK), and the United States (US), have developed 24-hour movement guidelines, with a common minimum recommendation being 60 minutes of daily moderate-to-intense PA for young people (Australian Government, Department of Health and Aged Care, 2021b; B. Smith et al., 2022; Tremblay et al., 2016; U.S. Department of Health and Human Services, 2018). These guidelines have helped with the identification of lower than optimal PA activity. In Australia, for example, only 2% of adolescents aged 13–17 have been found to meet the recommended daily PA guidelines (Australian Government, Department of Health and Aged Care, 2021a), and of particular concern is the low rate of adolescents aged 15–17 who meet critical strengthening activity guidelines (Australian Government, Australian Institute of Health and Welfare, 2024). However, these difficulties in implementation may be context-dependent. Therefore, relying on guidelines predominantly developed in the Global North creates a potential barrier to using PA as an effective active ingredient across the rest of the world. It is thus wise, if we want to meet the SDG Target 3.4 of good mental health and wellbeing globally, that researchers and policymakers work in partnership across nations to strengthen their research capacity to manage global mental health risks (SDG Target 3.D) within their contexts (The Global Goals, n.d.-a).

Normally, policies such as the movement guidelines are developed and informed by systematic reviews (e.g. Tremblay et al., 2016), which are a common strategy for summarizing broad research evidence to inform practice and policy, particularly in public health (Lhachimi, 2020). While systematic reviews remain a gold standard for synthesizing evidence (McSharry, 2023), bibliometric analysis introduces techniques that may have some advantages over more traditional review approaches. This method leverages quantitative and visualization techniques that map the key characteristics of publications, providing a graphical overview of research outputs beyond their contents and outcomes (Donthu et al., 2021). In particular, bibliometric analysis can be used to analyse a large body of relevant studies within a snapshot of time and identify features of articles such as influential authors and most productive regions, showing rising patterns and trends in a domain (Donthu et al., 2021; Zupic & Čater, 2015). A bibliometric analysis can provide insights into the cultural and contextual factors that might shape the production of this research, and how these could influence ‘what’ and ‘where’ this research is produced (Selvaratnam, 1988). The visualization techniques in bibliometric analysis may therefore offer informed insights into the state-of-the-art of a field in a way that may not be available with traditional literature reviews. Further, it can help researchers determine where there are new frontiers of research in order to build equitable research partnerships.

Conceptual model

The current study makes use of science mapping – a branch of bibliometric analysis (Zupic & Čater, 2015) – to surface and categorize the subtopics prioritized in past and present research on PA, depression, and anxiety in adolescents and young adults. Fellnhofer (2019) stresses that while systematic reviews are useful for evaluating previous research, science mapping enables thematic classification, which can be useful for forming a taxonomy of the knowledge base. The current study is influenced by Fuchs' (1993) sociological theory of scientific change, which indicates that 'resources and social structures shape how scientists perform their work' (p. 934). Hence, science mapping can also help make sense of where future meta-analyses and systematic reviews on research in PA and mental health in young people should occur, and where the research power in this field lies. It also enables macro-level trends to be visualized, which can help with making recommendations for future research, policy and practice (You et al., 2021; Zupic & Čater, 2015).

We adopt Hallinger and Kovačević's (2019) science mapping conceptual model as an organizing framework to focus on *space* (i.e. the geographical distribution of publications and collaborations), *composition of the knowledge-base* (i.e. the intellectual structure of research), and *time* (i.e. publication trends and changes in topics over time). Co-authorship analysis is used to understand collaboration between authors (Donthu et al., 2021). In the current study, we focused on the country of authorship to determine the geographical spread of research. Analyses of composition can be used to identify research trends, such as patterns or 'hotspots' (Hu & Zhang, 2015), as well as 'research fronts' representing newly emerging trends in the literature (Klavans & Boyack, 2017). Keyword co-occurrence analysis is used to identify these 'research hotspots' within a field (Zhang et al., 2022), and connecting keywords to publication date can highlight newly emerging research fronts (Hallinger & Kovačević, 2019; Klavans & Boyack, 2017). Connected keywords indicate that the topics represented by the terms are thematically linked (Donthu et al., 2021). In the current study, we only considered research published since 2010. Rather than attempting to analyse the entire history of the field, this publication period was chosen to focus on more recent research trends, with an eye on where research could be progressing into the future. Other bibliometric studies have also focused on small time windows (e.g. Andersen & Swami, 2021; Zhu et al., 2021), which is critical in health studies that need to look at the state-of-the-art to manage current crises.

Using Hallinger and Kovačević's (2019) framework, and drawing on co-authorship and keyword co-occurrence analyses, the current study addressed the following research questions:

- (1) What is the geographical distribution of recent research, and the collaboration networks of authors, on PA and depression/anxiety in adolescents and young adults? (i.e. *space*)
- (2) What are the research trends (patterns and hotspots) associated with recent research on PA and depression/anxiety in adolescents and young adults? (i.e. *composition of the knowledge-base* and *time*)
- (3) What research fronts are emerging in the field of PA and depression/anxiety in adolescents and young adults? (i.e. *time*)

Methods

Data source and search strategy

We drew from Donthu et al.'s (2021) bibliometric analysis guidance in the current study. The Scopus database was searched for literature related to PA and depression and/or anxiety in adolescents and/or young adults. Scopus was selected over alternative databases, such as Web of Science or PubMed, because it covers a broader range of journals (Falagas et al., 2008). Further, Donthu et al. (2021) recommend that only one database be used for a single bibliometric study to reduce the need for consolidation of sources, which can lead to human errors. We constructed the search string by adapting search terms and Boolean operators from previous bibliometric

analysis articles to find appropriate terms based around three key concepts: 'young people (adolescents and young adults)' as the *population*, building on the terms used by Hua et al. (2023); mental health specifically related to 'anxiety and depression' as the *effect*, using the same terms as Xu et al. (2021) and Zhou et al. (2021); and 'physical activity' as the *intervention*, based on the terms used by Memon et al. (2021) and Zhang et al. (2022). Since Zhang et al. included terms related to physical inactivity in their search terms, we also included them in our search string, as physical inactivity is increasingly linked with anxiety and depression, so it is relevant to the context of the current research. We omitted terms like 'depressed' or 'low mood', unless the terms, 'depression' or 'depressive disorder', were also mentioned. This was to ensure that only studies specifically about the mood disorder were included. Pilot testing of search terms was performed by searching Scopus for different words related to the key concepts. This was done to reduce false positives and negatives (i.e. to avoid excluding relevant literature or returning records that were not about the topic). We used the advanced Scopus search feature to limit the selection to peer-reviewed journal articles only, in the English language, and published from 2010 to 2022 (it should be noted that some publications had a 2023 publication year). Search terms were limited to appearing in the article title, abstract, and/or author keywords. The search was performed on 24 December 2022, and the retrieved records contained various metadata on relevant articles. The full search string is shown in Figure 1, along with the search strategy and screening process.

After all limiters were applied, 3,402 articles were retrieved from Scopus (see Figure 1). The titles and abstracts of these articles were then screened by one of the authors to remove duplicates and exclude papers that were deemed out-of-scope to the study. We used the WHO's definition of young people (10–24 years), as consisting of both adolescents (10–19 years) and youth (15–24 years), to help guide this screening process. Hence, we excluded investigations on animals and studies on human participants that explicitly focused on the elderly, pre-adolescents (e.g. elementary school children), and parents of young people. We also excluded studies about anxiety that were not explicitly mental health-related, such as classroom or learning anxiety, particularly if they did not measure anxiety as an underlying condition. Articles that focused on 'exercises' not related to PA, such as learning exercises, were also excluded. Finally, articles that were biographies, historical case studies and essays were excluded, because they did not involve any analysis or synthesis. Metadata for the final data set ($N = 2,668$ records) were cleaned by adding missing author keywords, derived from the titles and abstracts, to 331 records, and removing multiple affiliations for each author to only include their first reported affiliation.

Data analyses and visualisation

Python was used to produce publication and citation metrics. VOSviewer 1.6.18 (van Eck & Waltman, 2010) was used to perform co-authorship and keyword co-occurrence analyses. In both co-authorship and keyword co-occurrence analyses, countries/terms are clustered together and visualized in the form of network maps (see Figures 2, 3, and 4). The co-authorship analysis concerned research collaborations based on the country location of each author. For the keyword co-occurrence analysis, the map reflects the intellectual, or cognitive, structure of the field (Donthu et al., 2021; Zupic & Čater, 2015). In network maps, larger circles represent higher frequencies of the term (or country) in articles, and the thickness of the connecting lines shows that the terms appear together (co-occur) more within the same articles (Donthu et al., 2021). For the co-occurrence analysis, a keyword thesaurus was used to aggregate very similar terms and synonyms, as well as to remove generic or ambiguous words, country names, and method terms. After using the keyword thesaurus in VOSviewer, there were 1082 unique keywords across all studies. The keyword thesaurus and full-length data tables can be found in the Supplemental Materials. Interactive network maps can be found at https://osf.io/shb4m/?view_only=146ad6a613c7463399d6a9eaf5e5d271.

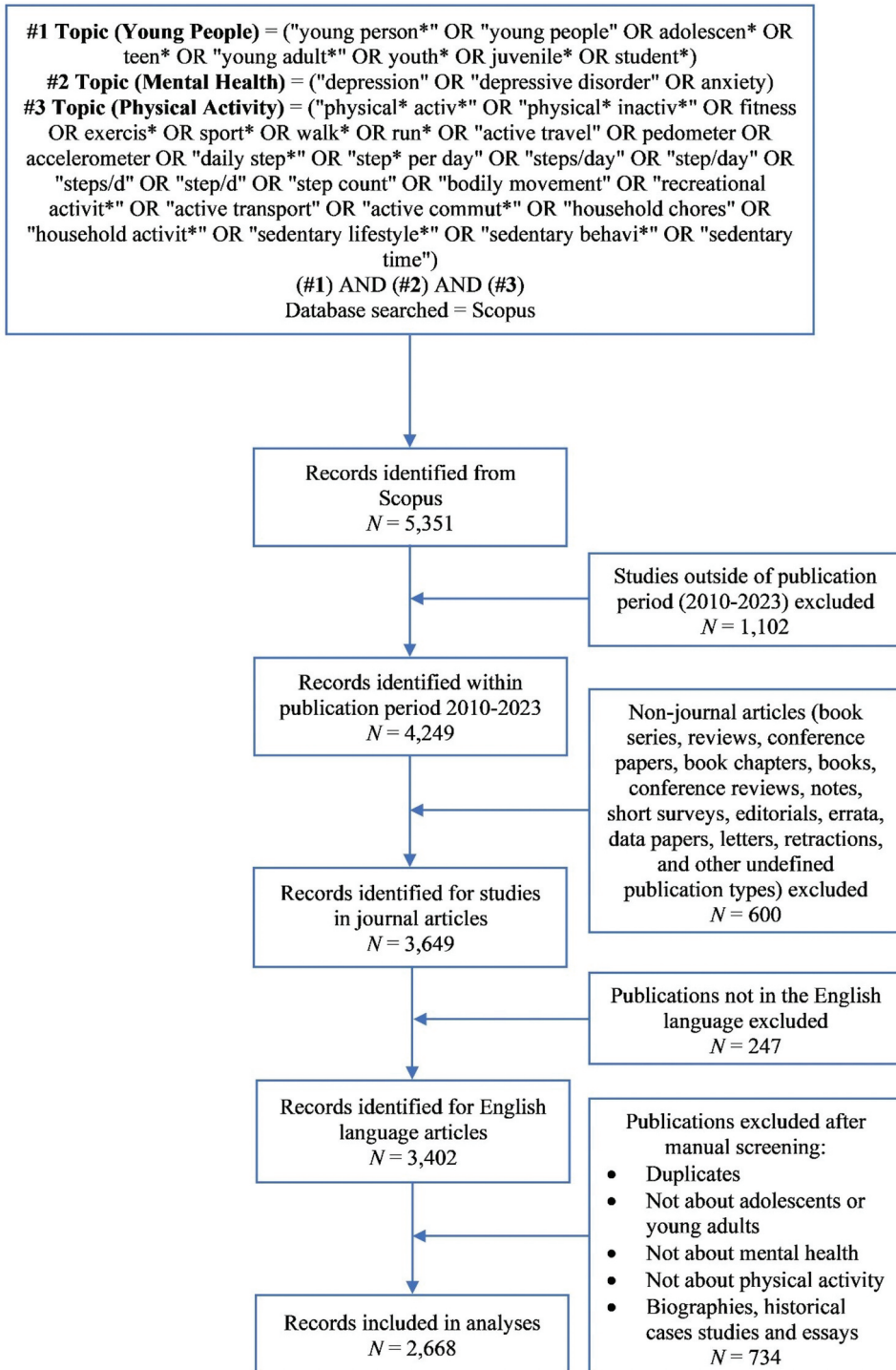


Figure 1. Search string, search strategy and data screening for science mapping.

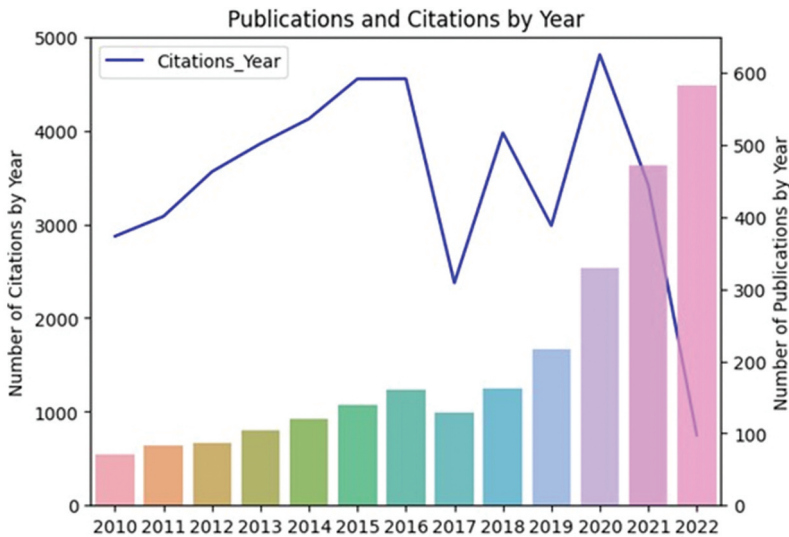


Figure 5. Yearly publications and citations count 2010–2022.

interpretability of the map. The colour range of the temporal overlay shows that the average publication year for many of the countries was between 2015 and 2020. Out of the top publishing countries, China had the most recent average publication year of 2020.

Keyword Co-occurrence analysis: established and emerging research trends

A network map visualizes the keyword co-occurrence analysis results in Figure 3. There were 4,388 links between terms. The three most common keywords were from the search terms (see Figure 1): ‘depression’ (711 occurrences, 178 links), ‘adolescents’ (647 occurrences, 177 links) and ‘anxiety’ (507 occurrences, 181 links). Other high-frequency keywords that were not search terms were ‘COVID-19’ (286 occurrences, 137 links), ‘stress’ (178 occurrences, 127 links), ‘obesity’ (129 occurrences, 103 links), and ‘sleep’ (103 occurrences, 94 links). The 193 analysed keywords formed seven clusters, each represented by a different colour in Figure 3. These clusters (see Table 1) are outlined below using literature from the data set that contributed to the construction of that cluster.

Cluster 1: chronic diseases, injuries and treatments

The first cluster (coloured red in Figure 3) encompassed keywords related to comorbid or chronic diseases and injuries, including pain (28 occurrences). Chronic and comorbid conditions, such as diabetes (27 occurrences) and cardiovascular diseases (23 occurrences), have been frequently linked with depression and anxiety, and can affect adolescents’ and young adults’ participation in PA (McKillop et al., 2018; Sumartini & Putri, 2021). Sports participation can lead to injury (24 occurrences)

Table 1. Clusters of research on physical activity, depression, and anxiety in adolescents and young adults.

Cluster Number	Cluster Colour	Cluster Label	Number of Keywords
1	Red	Chronic Diseases, Injuries and Treatments	44
2	Green	University Students and Stress	44
3	Dark Blue	Sport-related Activities	38
4	Yellow	Weight and Eating Concerns	22
5	Purple	Health Risks	20
6	Light Blue	External Support Structures	13
7	Orange	COVID-19-related Issues	12

and injury-related conditions, particularly for those with a chronic condition (Berg et al., 2018). The link between concussion (54 occurrences) and depression and anxiety has become an increasing concern in recent years (Schulze et al., 2022), particularly in athletes (Chrisman et al., 2017).

Other issues, such as chronic pain (18 occurrences), back pain (14 occurrences), and musculoskeletal pain (14 occurrences), also emerged as topics closely related to injury, such as associations between pain and fear of movement due to fear of re-injury (Andias & Silva, 2022). General keywords, such as intervention (86 occurrences), epidemiology (44 occurrences), prevention (43 occurrences), and treatment (38 occurrences), were the most frequent keywords in cluster 1. In terms of treatment approaches, CBT (33 occurrences) and rehabilitation (21 occurrences) were the most common. CBT is a major type of psychotherapy (16 occurrences) for treating depressive and anxiety disorders across a range of contexts.

Cluster 2: university students and stress

The second cluster (green) included terms related to university students (242 occurrences) and stress (178 occurrences), along with a focus on achieving student wellness (13 occurrences) through stress management (13 occurrences) to build resilience (50 occurrences) and coping (44 occurrences). Secondary school students were also represented in this cluster but with only 12 occurrences, so the focus was on tertiary students, and undergraduate students (22 occurrences) in particular. Medical students (76 occurrences), nursing students (25 occurrences), health students (14 occurrences), and medical education (20 occurrences) were keywords that specifically focused on health disciplines. Amplified mental health issues have been found among these students in particular, perhaps due to unique stressors, such as test anxiety (14 occurrences) and the perceived higher demands of studying these fields (Irmak Vural et al., 2019; Waqas et al., 2015).

The keywords, aerobic exercise (34 occurrences) and heart rate (29 occurrences), appeared to stem from studies that highlighted the strong positive effects of fitness on mental health. Additionally, yoga (21 occurrences), Chinese mind-body exercises (13 occurrences), and mHealth (17 occurrences) (e.g. running and fitness apps) are alternative approaches that have emerged as non-pharmacological PA interventions for improving students' mental health (Montagni et al., 2018; J. A. Smith et al., 2011; Wang, 2020). Many of these interventions directed towards student wellbeing appear to be constructed around complementary therapies, such as mindfulness (70 occurrences), meditation (19 occurrences), relaxation (25 occurrences), and self-care (16 occurrences) (e.g. Alimehdi et al., 2016). Interventions have also been designed to target some of the contemporary issues students face, such as cases of academic burnout (23 occurrences) and poor sleep quality (46 occurrences) (Hatami et al., 2013; Wild et al., 2014).

Cluster 3: sport-related activities

The third cluster (dark blue) had a particular focus on PA terms related to sport (123 occurrences), mostly in the context of competition, such as team sports (44 occurrences), coaching (12 occurrences), training (13 occurrences), athletes (56 occurrences), physical education (31 occurrences), and sports psychology (15 occurrences). At the core of this cluster was anxiety (507 occurrences) as its highest-frequency keyword, further delineated into subtypes that were often linked with sport participation and performance (19 occurrences): social anxiety (29 occurrences), fear/phobias (17 occurrences), social physique anxiety (17 occurrences), and competitive anxiety (15 occurrences). Both anxiety in general, and social physique anxiety, act as barriers to participation in sport and exercise (253 occurrences), particularly during adolescence (Gregory et al., 2022; Sicilia et al., 2014). Similarly, competitive anxiety can impact on sporting performance (Alejo et al., 2020; Ong & Griva, 2017). An innovative intervention for sports participation was virtual reality (VR) (13 occurrences). As an intervention, VR has been used to reduce anxiety by giving the illusion of movement (Burin et al., 2022), or as an exergame to encourage exercise at home in short bursts to reduce school stress (Shaw & Lubetzky, 2021). Body image (52 occurrences) and self-esteem (39 occurrences) were also high-frequency keywords in this cluster.

Cluster 4: weight and eating concerns

The fourth cluster (yellow) included terms associated with weight and eating concerns: obesity (129 occurrences), body weight (53 occurrences), weight-related behaviours (18 occurrences), eating disorders (68 occurrences), eating habits (28 occurrences), and diet (67 occurrences). Depressive symptoms (99 occurrences) was the key mental health keyword in this cluster, with obesity a significant risk factor for depression in adolescents (Alsaleem, 2021). Obesity has been linked with other factors in this cluster, such as sleep (103 occurrences) (Naab et al., 2022) and cardiorespiratory fitness (15 occurrences) (Ajisafe, 2019). Terms related to healthy lifestyles (22 occurrences), including healthy diet (12 occurrences) and nutrition (37 occurrences), were also part of this cluster. Females (25 occurrences) being specifically part of this cluster also suggests there is a gendered focus in this sub-area of research.

Cluster 5: health risks

The fifth cluster (purple) included adolescents (647 occurrences) as its highest-frequency keyword. Health risks (18 occurrences), such as smoking (33 occurrences), substance use (26 occurrences), and alcohol (23 occurrences) were also part of this cluster. Participation in these risky activities often commences during adolescence, and they have been linked with mental health problems (Mangerud et al., 2014; Skogen et al., 2014). Substance use has been frequently associated with heightened depressive and anxious symptoms in individuals (Kumar et al., 2020; Zakaria et al., 2021), including those with a chronic illness (17 occurrences), such as cancer (Asvat et al., 2020). Substance use that turns into addiction during adolescence could lead to further risk behaviours (13 occurrences), such as problematic gambling (Weinberger et al., 2015). Studies investigating sleep have often explored its correlations with PA and substance use (e.g. Rosso et al., 2020). Sleep disorders (40 occurrences) was one of the highest-frequency keywords in this cluster.

There were also a number of studies that focused on the effects of short sleep duration (27 occurrences) (e.g. Wei & Liu, 2022), and its associations with PA (e.g. Wolf & Rosenstock, 2017), with some of these studies examining gender differences (22 occurrences) (e.g. Chang & Choi, 2016; Langvik et al., 2019). This cluster also contained the most severe outcomes of mental health problems: suicidal behaviour (35 occurrences) and suicidal ideation (22 occurrences). Reduced sleep has been associated with suicidal ideation (Sarchiapone et al., 2014). Loneliness (21 occurrences) and risky behaviours (such as substance use) have been found to increase the odds of suicide attempts (Oppong Asante et al., 2021). Bullying/victimization (22 occurrences) being part of this cluster could also provide one explanation for some of the negative health behaviours (53 occurrences).

Cluster 6: external support structures

Cluster 6 (light blue) was comprised of keywords related to health promotion (23 occurrences) and external support structures, including the development of skills to improve and maintain an individual's levels of wellbeing (101 occurrences). Social support (27 occurrences) indicates the importance of a peer support network, as it has been found to be one of the most commonly effective coping mechanisms for adolescents dealing with stress (Nagy-Pénzes et al., 2020). Social skills (14 occurrences) are also important and interventions have been used to develop them, particularly in individuals who might lack these skills due to their mental health issues (Lambelet et al., 2017). Nuryadi et al. (2019) conducted a study on students who participated in group sports, individual sports (15 occurrences), or no sports. The group with no sporting activity had high cortisol (24 occurrences) hormone levels, meaning they were more prone to anxiety. In comparison, the group of students who participated in individual sports had lower cortisol levels, while the team sports students had the lowest cortisol levels.

Other keywords in this cluster, such as physical inactivity (21 occurrences), walking (15 occurrences), and leisure time (13 occurrences), are most likely drawn from research on wellbeing through correcting self-motivation barriers and encouraging self-health. Walking in nature appears to lower

cortisol levels more than walking in urban areas, resulting in lower anxiety, reduced negative emotions (12 occurrences), and more positive mood states (14 occurrences) (Joung et al., 2020).

Cluster 7: COVID-19-related issues

The last cluster (orange) included depression (711 occurrences) as its highest-frequency keyword, and some of the most recent keywords by average publication year. Impacts of the COVID-19 (286 occurrences) pandemic on anxiety and depressive disorders in young people have been widely reported (e.g. Hawes et al., 2022). Many of the terms clustered with COVID-19 could be unique to quarantine (18 occurrences) and lockdown (21 occurrences) strategies in certain nations at the height of the pandemic, with the following high-frequency keywords being present: sedentary behaviour (98 occurrences), screen-time (49 occurrences), internet use (27 occurrences), and social media (20 occurrences).

Temporal changes

Finally, a temporal overlay was added to the keyword network map to explore shifts in research foci over time and highlight any research fronts (Figure 4). Terms related to weight, such as 'body image', 'body weight', 'weight-related behaviours', and 'obesity', had some of the earliest average publication years of keywords in the data set. Most of this research occurred around 2015–2018, as indicated by the colour overlay. Terms including 'treatment', 'intervention', and 'CBT' also appeared, on average, around the midpoint (2017). The keywords with the most recent average publication year (2021) were 'COVID-19', 'screen-time', 'quarantine', 'pandemics', and 'lockdown'. Other terms that were not clustered with 'COVID-19', and appeared, on average, later in the sampling period (2019–2020) included 'virtual reality', 'sleep disorders', 'sleep quality', 'loneliness', and 'mHealth' (mobile health). This showed a shift in topic trends that were influenced by developments and events throughout the decade.

Discussion

This research aimed to understand the trends, pluralization and global context of research on PA, depression and anxiety in young people through science mapping. We propose that the findings could be used as a guide by researchers when identifying potential gaps and avenues that could be addressed in future research, as well as by policymakers who are attempting to realize the SDG targets of good mental health. We will now address each research question to explore the implications of this research.

What is the geographical distribution of recent research, and the collaboration networks of authors?

With the exception of China, the majority of publications arose from authors with primary affiliations in countries in the Global North. With the US having the most international collaborations, it could be argued that it is shaping the global discourse of research in this space and perhaps has the most global scientific power in this field. Authors in certain nations in the Middle-East and Eastern Europe have not been part of any international collaborations in this field, so they may have limited opportunities to work with researchers in countries with more access to funding. As there are isolated pockets of research from this field in these regions, government research funding bodies, particularly in the Global North where they are committed to building partnerships to meet the SDG goals, may want to prioritize the building of research networks and partnerships with these countries to help develop better global mental health.

The lack of studies from authors in the Global South could indicate a major gap in the field. Additionally, although authors in high-income countries may still be studying populations in low- and middle-income countries (LMICs), the keyword 'LMIC' did not reach the minimum threshold for

inclusion in the co-occurrence analysis, suggesting that there was not a large presence of studies focusing on these regions. Stigma associated with mental health in LMICs may act as a barrier to the implementation of interventions (Le et al., 2022), which is also likely to make it difficult to carry out research on the efficacy of such approaches. It could also be the case that PA interventions are less of a priority in these countries due to depression/anxiety being linked to other factors (e.g. poverty). Hence, this lack of research signals the need to build and strengthen the research capacity of researchers and policymakers in these regions; otherwise, they will continue to be limited in the extent of their contribution to, and contextualization of, localized policymaking for reductions in mental health risks in their nations.

Finally, the US and UK may have more representation due to the impacts of media addiction. With much of the research in the field being produced in the US, which favours Western-centric philosophies focusing on the individual, this may unintentionally suppress more radical ideas around PA coming from the Global South (Affun-Adegbulu & Adegbulu, 2020), or indigenous approaches, such as traditional PA (Akbar et al., 2020). Greater emphasis on community wellbeing and mental health for young people could perhaps create more systemic and structural level change. Hence, indexing websites, such as Scopus, need to play a part in helping to decolonize the research power by indexing Global South journals. However, the lack of research from the Global South could simply be due to the exclusion criteria used in the review (see Limitations section).

What are the research trends associated with recent research?

Through a qualitative interpretation of the keywords that clustered together, each research theme/hotspot was labelled (Table 1). While there are still connections occurring between keywords across clusters, as shown by the links in Figure 3, the co-occurrence analysis does indicate dominant subtopics, which could help future researchers to identify gaps, such as the potential for new subtopics that are thus far underexplored.

The results show an evolving pattern of studies within the selected time-period, which have generally been shaped by national conversations and major events in the last decade. One such example of shifting trends is suggested by the average publication years for keywords related to obesity and weight-related behaviours coming earlier in the decade, compared with sleep taking on more prominence in recent studies. This may be because weight loss itself does not appear to be a mechanism in the reduction of mental health issues (King et al., 2020), whereas alongside PA and diet, sleep has been categorized as part of the 'big three' health behaviours that play a vital role in the healthy mental wellbeing of young adults (Wickham et al., 2020). Interestingly, the cluster related to weight and eating concerns (Cluster 4) had females as a specific keyword, but not males, suggesting that there is a lack of focus on how these issues might also impact on males, prompting the need for further studies.

Several clusters highlighted keywords that could act as barriers to participating in PA, limiting the extent to which it can act as an effective intervention. For example, chronic diseases and pain can impact the accessibility of PA (McKillop et al., 2018; Sumartini & Putri, 2021), so research on the efficacy of multifaceted approaches to PA may be of value. A review for the UK Chief Medical Officers has also called for the development of PA interventions for young people with disabilities (B. Smith et al., 2022), meaning that there is a need for programmes that consider mental and physical barriers. Terms such as prevention, treatment and intervention were clustered with more traditional therapeutic approaches, such as psychotherapy and CBT. However, the earlier average publication year for CBT-related studies indicates a diminishing emphasis in contemporary PA research.

The dominance of research on university students is likely due to enormous attention by popular media on the mental health of students in higher education across the decade, as well as increased disclosure amongst young people (Rückert, 2015). Yet, this finding could also suggest that there is room for further research on secondary students, as this term appeared to be far less represented in the keywords. With the significant potential for mental health

disorders developing during adolescence (Essau et al., 2014), there might be a need for research on preventative approaches that consider the early-youth period before the commencement of university.

The clusters also showed a distinction between the effects of team and individual sports, suggesting that PA interventions need to particularly focus on the mechanisms in PA that cause improvements in depression and anxiety. Pluhar et al. (2019) observed a smaller number of team sport athletes in their sample reporting anxiety or depression than individual sport athletes. Pluhar et al. assumed this was due to goal-oriented motivations in individual athletes, compared to team sports athletes participating for fun and stress relief, so they posited that the social aspect of team sports likely plays an important role in this. Nuryadi et al. (2019) theorized that the lower cortisol levels they found in those participating in group sports were due to its focus on training teamwork and self-confidence. However, Desjarlais and Willoughby (2010) found that where participation in organized sports was unrelated to friendship quality, it did not alleviate social anxiety in adolescents. Therefore, if social connections play a vital role in the PA activities that reduce anxiety and depression issues, there is a need to understand what types of sports cultivate the social connections that reduce adolescents' anxiety and depression.

What research fronts are emerging?

Emerging research fronts focused on alternative therapies, new technologies, and the impacts of COVID-19 on sedentary behaviour. More than half of the studies in the sample were published from 2020 onwards, coinciding with the effects of COVID-19. While COVID-19 was a key event that triggered an enormous body of research into its impact on the mental health of young people, it can also be seen to have exacerbated issues that were burgeoning prior to the pandemic. Excessive screen-time, sedentary behaviour, and internet use were already trending topics in the mental health of young people. The lockdowns saw a rise in concerns about these problems, and in the post-COVID-19 context, these are significant issues with extensive media and research coverage. For example, correlations have been found between social media use and heightened anxiety and depression in adolescents (Keles et al., 2020), while a 2021 survey indicated that medical students who were already experiencing depression were more likely to be sedentary and engage in screen-time for longer periods than those who were not depressed (Tashiro et al., 2022). These challenges appear to underpin a growing need for approaches and interventions that motivate young people who may be averse to traditional strengthening activities such as sport and strength resistance training.

In the post-COVID-19 era, research indicates that participation in community sports have decreased (Eime et al., 2024). In light of the apparent benefit of social connections in group sports for anxiety and depression (Desjarlais & Willoughby, 2010), this may be an important area of ongoing focus. The long-term picture regarding participation in community sports and group exercise must continue being investigated. In terms of alternative approaches and new technologies, the later average publication years for yoga, Chinese mind-body exercises, mHealth, and VR indicates that research may be exploring the potential for encouraging young people who are disengaged with PA through more creative interventions. Although not seen in this science mapping review because of the timeframe, generative artificial intelligence may also be an area of emerging exploration within this field. Hence, researchers across nations may want to further strengthen their partnerships (North–South, South–South and its combinations) by investigating indigenous therapies and new technologies that may be useful or adaptive to different contexts. This approach will allow the decolonization of mental health therapies (Gone, 2013, 2021) and the ability to test and explore new innovations.

Limitations

Various aspects of the search strategy and data screening process might have led to crucial research being omitted: a single database was used, meaning that publications only indexed within other databases were not included; the search was limited to peer-reviewed journal articles only, meaning that grey literature, chapters, etc., were excluded; non-English Language articles were not considered, which is likely to have impacted on our understanding of the geographical reach of research in this area. Further, manual screening and a single author screening all records (for expediency purposes) means the potential for human error was also introduced. Using a keyword thesaurus might not have represented the right level of granularity or combined all relevant keywords together. Similarly, in manually screening titles and abstracts, it was not always possible to definitively confirm that all studies investigated PA as it is defined by the WHO, or that the age ranges of study participants were specifically between the ages of 10–24 (the WHO's definition of young people). The results of the current study should be viewed and interpreted within the context of these constraints.

Conclusions

This study has shown the potential of science mapping for gaining a wider understanding of the characteristics of the scientific literature in terms of the geographic distribution, networks, research trends, and research fronts in this field. Its visualization techniques provided insight into the intellectual structure of this field. Reflecting on Fuchs' (1993) theory, we note that some of the research hotspots may be transient, as they are driven by global and cultural contextual factors, such as the COVID-19 pandemic, policymakers' interests, and popular media, as well as where funding is available. However, more established research areas are appearing to emerge, such as those embracing different PA methods, including alternative therapies and new technologies. Future analyses could focus on studies from countries that were not represented in the Scopus database. More collaboration with authors from LMICs may be beneficial to opening up the field beyond dominant Western philosophies if the populations being studied are also from these regions. This could help us to understand how PA interventions function across different cultural contexts. In addition, research trends and fronts highlight growing topics that can help inform the development of public health recommendations.

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