COVID-19 and Telework: the effects of visual display units on vision in the spotlight. A bibliometric overview

COVID-19 y teletrabajo: los efectos de las pantallas digitales sobre la visión en el foco. Una visión bibliométrica

Paula Pérez-Espinel[1] https://orcid.org/0000-0003-4341-4118

Howard Ramírez-Malule[2] https://orcid.org/0000-0003-1013-5809

David Gómez-Ríos[2*] https://orcid.org/0000-0002-9858-9559

[1]Conestoga College, School of Health & Life Sciences. ON, Canada.

[2]Universidad del Valle, Escuela de Ingeniería Química. Cali, Colombia.

[*]Autor para la correspondencia: david.andres.gomez@correounivalle.edu.co

ABSTRACT

The virtualization of office-work and education activities under contributed to a substantial increase on the use of digital devices with screens (computers, smartphones and tablets), with the consequent implications in terms of risks associated with prolonged exposure to visual display units. This study aims to provide a bibliometric analysis of the scientific literature on telework, visual health, and computer vision syndrome to understand the impact of increased screen time due to telework and virtual education on visual health. The Scopus database was utilized to retrieve relevant publications. The search included 4615 documents on telework, 368 on visual health, and 369 on computer vision syndrome. The analysis focused on identifying trends and the volume of research over time, particularly in

the context of the COVID-19 pandemic. Before 2020, telework and its associated visual health issues were underexplored by the scientific community. The pandemic resulted in a significant increase in publications, particularly regarding telework and computer vision syndrome. The bibliometric analysis revealed a strong connection between COVID-19, occupational health, and visual health topics. Despite the increased attention, computer vision syndrome remains an emerging topic with limited scientific evidence. The sudden shift to remote work and online education during the lockdown put in the spotlight the potential risks of the prolonged exposure to visual display units. In this sense, continued investigation is required to understand the long-term implications of excessive screen use on visual health, including the effects of blue-light radiation and the potential increase in myopia, and their impacts on occupational health.

Keywords: telework; virtual education; computer vision syndrome; visual display unit; COVID-19; visual health.

RESUMEN

La virtualización del trabajo y la educación incrementó el uso de los dispositivos digitales con pantallas (computadoras, teléfonos inteligentes y tabletas), lo que conllevó riesgos asociados a la exposición prolongada a las unidades de presentación visual. Este estudio realizó un análisis bibliométrico de la literatura científica sobre el teletrabajo, la salud visual y el síndrome de visión por computadora. Se utilizó la base de datos Scopus para recuperar las publicaciones relevantes. La búsqueda incluyó 4615 documentos sobre el teletrabajo, 368 de salud visual y 369 acerca del síndrome de visión por computadora. El análisis se centró en identificar las tendencias de la producción científica en el contexto de la pandemia de la COVID-19. Antes de 2020 el teletrabajo y los potenciales problemas asociados con la salud visual habían sido poco explorados. La pandemia resultó en un aumento significativo de publicaciones, especialmente en relación con el teletrabajo y el síndrome de visión por computadora. El análisis bibliométrico reveló una sólida conexión entre la COVID-19, la salud ocupacional y los temas de salud

visual. El síndrome de visión por computadora continúa siendo un tema emergente con evidencia científica limitada. La adaptación repentina al trabajo remoto y la educación en línea durante la cuarentena destacó los posibles riesgos de la exposición prolongada a las unidades de presentación visual. Aún se requieren más investigaciones para comprender las implicaciones del uso excesivo de pantallas en la salud visual a largo plazo, los efectos de la radiación de luz azul, el posible aumento de la miopía, y sus impactos en la salud ocupacional.

Palabras clave: teletrabajo; síndrome de visión de computadora; pantallas digitales; COVID-19; salud visual.

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Introduction

In December 2019, several cases of atypical pneumonia were reported in the Chinese province of Hubei triggered a series of events that would lead to 118 national o partial lockdowns around the world, due to the widespread of SARS-CoV-2 virus and the associated respiratory disease COVID-19. The COVID-19 arrived at Latin America via the international flights and rapidly the continent and almost all countries in the world closed all land, sea, and river borders during a mean period of 100 days (first lockdown).[1] Hereinafter, successive local and national lockdowns took place according to the current epidemiological conditions during the next 14 months.

Such “mitigation lockdown” aimed at flattening the curve of cases to avoid the health system collapse in almost every country, while vaccines or other treatment alternatives were developed. The lockdowns restricted the mobility of citizens,

educational services and non-essential activities in the public and private sectors. During these periods employees and employers implemented measures to avoid the termination of contracts and to maintain the production and services. Among those measures, the home office, remote work, teleworking and virtual education, all mediated by the information and communication technologies (ICTs), suddenly replaced the usual daily activities of millions of people in the world. Thus, the response to COVID-19 pandemic forced the implementation of virtualization strategies in different economic sectors aimed to minimize personal contacts while maintaining economic activity as much as possible.

In this context of economic and social changes, virtual education and telework became the cornerstone of preserving jobs and education while reducing exposure and contagion risks. Telework, remote work and telecommuting, while often used interchangeably, even in literature, have distinct meanings. Telework is the broader definition including any work conducted outside a traditional office environment using information and communication technologies. This can encompass working from home, satellite offices, coworking spaces, or any remote location, offering a high degree of flexibility in terms of where and how work is performed. Telecommuting specifically refers to working from home or a location near home, with the primary goal of reducing or eliminating the daily commute to a central workplace. Nevertheless, with independence of the place or form of connection, it implies the use of ICTs, and hence a visual interphase through a digital screen.[2] Likewise, distance and virtual education are also used interchangeably, despite virtual education refers only to learning taking place entirely online, utilizing digital platforms and tools to deliver coursework, lectures, interactive activities. Distance education, on the other hand, covers any form of education where students are not physically present in a traditional classroom setting. In modernity, distance education involves, majorly, online components owing to the widespread use of ICTs in people of all ages and social levels, while correspondence courses, video recordings, and other non-digital methods are falling in disuse.[3]

Despite both distance/virtual education and telework/telecommuting initiatives were being implemented in specific cases to facilitate the access to public services

in many areas worldwide, those efforts were marginal compared to the drastic change caused by the COVID-19 pandemic. In the European Union up to 2019, only a 5.4% of the employees worked from home. Similarly, in the United States only 4.1% of the U.S. workforce telecommuted half-time or more before the pandemics.[4,5] By the end of 2021 when the pandemics was considered almost overcome those shares triplicated.

Despite telework has been motivated in the last years by the local and national legislations, mainly due to multiple benefits in mobility, sustainability and work-life balance.[2] Undoubtedly, the forced and sudden adaptation to the lockdown conditions have contributed to reduce the resistance to the implementation of virtualization and telecommuting in the organizations.[2,6] Nevertheless, discussions have arisen about ergonomic, psychological and visual system hazards caused by long-term work in electronic devices from home. Scientific evidence alerts that continuous work involving visual display units (VDUs), i.e. computers, smartphones and tablets, might be associated to negative effects on visual health,[6,7] and exposition to those devices increased substantially during the pandemics for both, work and recreational purposes.[8,9] Moreover, the statistics on telework implementation indicate that after the control of the pandemic telework stayed.[4,5] Thus, the present contribution aims to present a bibliometric landscape of the scientific output related to the computer vision syndrome (CVS) resultant from continuous exposition to VDUs.

Methods

Scopus is the largest database of scientific literature, containing about 27950 titles, of which 14200 are peer-reviewed journals. The content in the database distributes as follows, according to knowledge area: 31.3% physical sciences, 26.0% health sciences, 17.7% life sciences and 25% social sciences.[10] Thus, Scopus database was used to identify the more relevant publications connecting telework/telecommuting with CVS and digital eye strain. Although different, the

keywords telework and telecommuting are often used interchangeably, even in scientific literature. The keywords selected were searched in the title, abstract, and keywords fields and combinations by using the Boolean operators “OR” and “AND” where implemented were necessary to correlate frequent terms in specific topics. The retrieved data included (i) citation information, (ii) bibliographic details, (iii) abstracts, (iv) keywords, and (v) funding information, refined by timespan and cleansed of duplicates and errors. This curated dataset was used for the analysis of bibliometric indicators and the creation of bibliometric networks using VOSviewer 1.6.16 software. The criteria set for analysis required at least one document from a country and a minimum of five keyword occurrences. Keywords were further processed in Microsoft Excel® to refine the thesaurus. Furthermore, no time and document type restrictions were applied in the search. VOSviewer Software was used for data visualization and bibliometric networks generation.[11]

The first search was carried out using the following search syntax: TITLE-ABS-KEY (telework) OR TITLE-ABS-KEY ("remote work") OR TITLE-ABS-KEY (telecommuting). Timespan: 1964-2022.

The second search was carried out using the following search syntax: TITLE-ABS-KEY ("visual health"). Timespan: 1952-2022.

The third search was carried out by using the following search syntax: TITLE-ABS-KEY (“computer vision syndrome”) OR TITLE-ABS-KEY ("digital eye strain"). Timespan: 1993-2022.

As indicated, the terms of the three searches were not crossed, and the connections between the topics were visualized directly in the bibliometric networks. Additionally, titles and abstracts of records were meticulously reviewed, with many articles read in full to ensure thorough analysis, aiming at providing a comprehensive discussion of most relevant findings related to the prolonged exposition to VDUs for studying and/or working. The following bibliometric indicators were considered:

Output: The total number of publications or documents produced per year since the first publication.

Growth Rate: The percentage of change at which the number of publications increases or decreases between years.

Number of Citations: The total count that a publication has been cited by other works as a measure of the impact or influence of the research.

Authors' h-index: A metric that measures both the productivity and citation impact of an individual author's publications. The h-index indicates that the author has 'h' papers each cited at least 'h' times.

Bibliometric keyword's network: Visual representations of the most frequently occurring keywords, showing relationships and clusters among research topics.

Results

The first search retrieved 4615 documents related to the topic of telework in the Scopus database, which 63.2% are indexed as research articles and 4.8% as reviews. Figure 1A displays the evolution of the number of papers in the topic between 1964 and 2022. The scientific production in the topic of telework/telecommuting/remote work has not followed an exponential trend (R^2 = 0.57); conversely, the production was rather constant from 1996 until 2019. Notice the sharp increase in the number of publications in the period 2020-2022. The lockdowns applied worldwide as part of the response to the COVID-19 pandemic awoke the scientific interest about different aspects of remote work application, since it was a new scenario for the most of companies and public servers in the world. 54.5% of the total scientific production on telework has been published between 2020 and 2022. Social sciences contributed the highest share of published works (18.4%) followed by computer science (14.3%), business, management and accounting (12.4%), engineering (11.8%) and medicine (10.5%). The United States (32.9%) is the main contributor country, then, United Kingdom (6.7%), Canada (4.8%), Japan (4.6%) and Australia (4.3%) complete the top-five of main contributor countries.

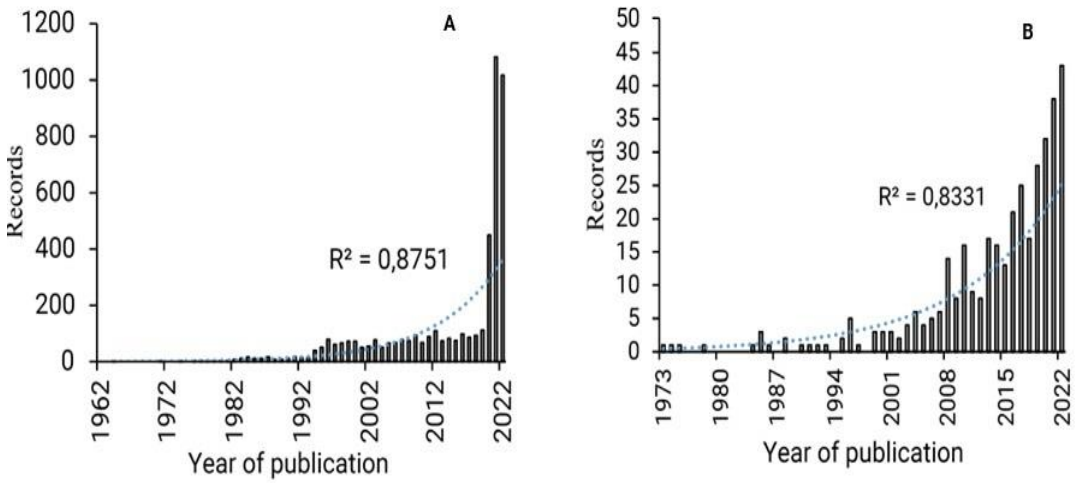

Fig. 1 – Evolution of the number of records on telework and visual health indexed in the Scopus database. A: Records on telework (1962-2022). B. Records on visual health (1973-2022).

Figure 1B shows the evolution of number of publications on visual health between 1973 and 2022. This production trend fitted better to an exponential (R^2 = 0.92), although the number of records per year is relatively low. Through the search process, a total of 368 documents were obtained (second search) from journals indexed in Scopus database, which 73.4% of them correspond to research articles. Prior to the 2000s, few studies were published in this field, but the growth in the number of papers per year was exponential after the century transition up to the present day. This suggests a rise in the interest on the topic, possibly connected to the current and future increase of the prevalence of visual pathologies.[12] The highest rate of publication has taken place between 2018 and 2022. The leading contributor countries in the field are the United States (31%), China (12%), the United Kingdom (8.8%), Spain (7.2%) and Canada (5.4%), while medicine (38.3%), health professions (6.8%) and engineering (6.6%) were the knowledge areas in which the researchers were more focused.

Figure 2 displays the co-occurrence of the most used author's keywords among the papers published in time-period evaluated as a proxy of the most frequent topics in

in connection with telework. Eight clusters and thirty-six nodes were observed and the minimum frequency of occurrence for a keyword was ten. COVID-19 is the biggest node in the network, evidencing the profuse scientific output relating telework with the global response to the pandemics and it is accordance with the high number of articles published in the last three years. Indeed, the COVID-19 pandemics marked an inflection point in the interest/necessity of implementing remote work on organizations, and the scientific community also increased its interest on the topic as a relevant field of study. Additionally, communication and information technologies (ICT), digitalization, e-learning, ergonomics, mental and occupational health, and organizational aspects appear as relevant clusters connected to telework.

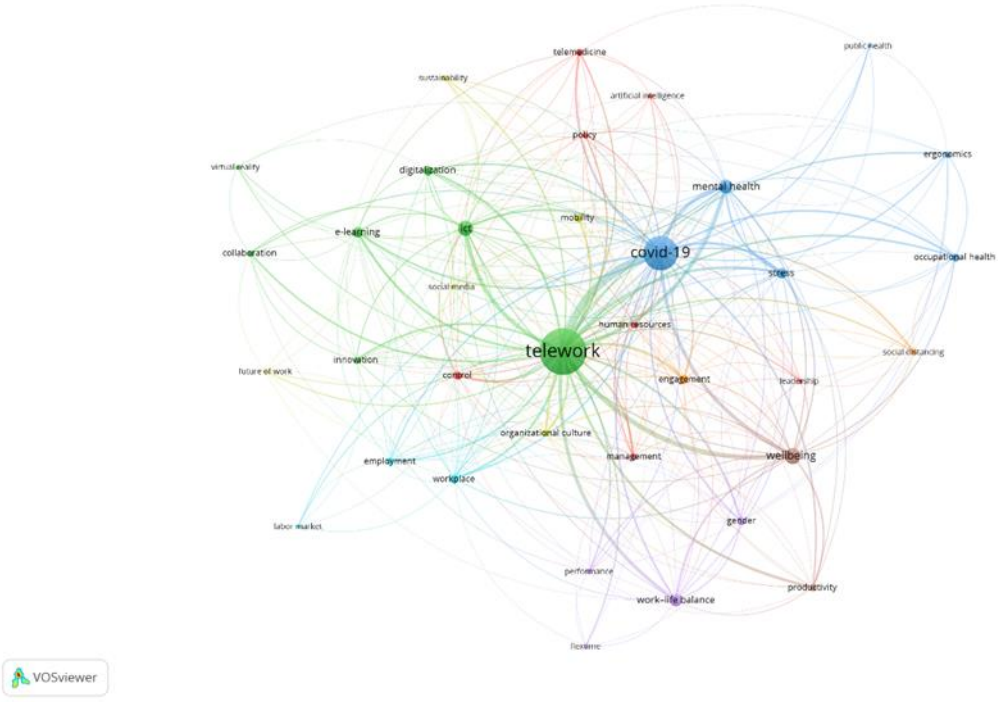

Fig. 2 – VOS viewer bibliometric network of most frequently mentioned author keywords on global output on telework and visual health: Telework (minimum number of occurrences: 10).

Similarly, figure 3 shows the co-occurrence of the most used author's keywords among the papers published in time-period evaluated in visual health. Ten clusters

and a total of fifty-eight nodes were observed. It is important to highlight the appearance of COVID-19 as one of the current relevant topics related to visual health. Several nodes about specific eye pathologies/conditions like myopia, macular degeneration, uveitis cancer, low vision/blindness are observed. However, there is a relevant number of nodes connected to continued use of VDUs (computer terminals, smartphones): visual fatigue, asthenopia, ergonomics and occupational health.

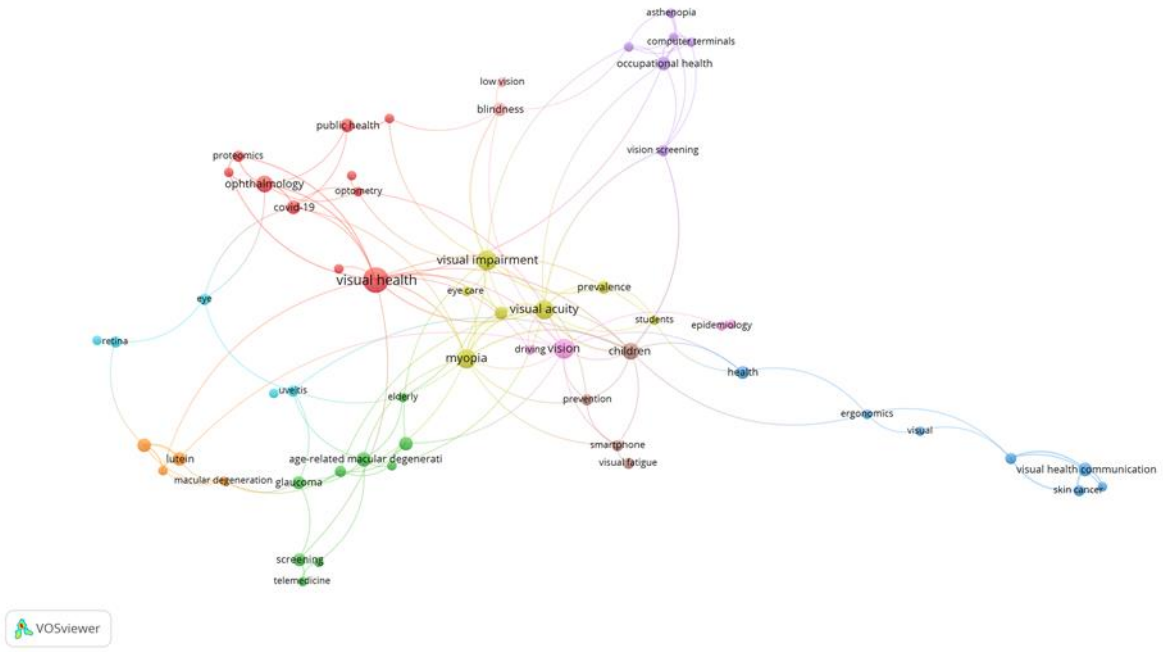

Fig. 3 – VOS viewer bibliometric network of most frequently mentioned author keywords on global output on telework and visual health: Visual health (minimum number of occurrences: 3).

A total of 369 records were retrieved between 1999 and 2022, related to CVS and digital eye strain; 67.2% are research articles, 14.6% conference papers and 10.6% reviews. The evolution of the number of publications for both, CVS and digital eye strain, is shown in figure 4. During the timespan 2000-2010, 44 documents were retrieved. However, the interest on the topic was slowly growing, from 2011 to 2019 at a mean of 14 papers per year. But in 2020 the number of records of 2019

duplicated, and in 2022 duplicated again. Thus, 52.5% of the total number of publications regarding the CVS have taken place in the context of the pandemics. The growth trend in the number of contributions is approximately exponential (R^2 = 0.89), with a remarkable growth in the last 6 years, where the influence of the pandemics motivated an increase in the number of investigations in the topic. The number of records on digital eye strain is considerably lower, since the term "computer vision syndrome" is more widely used. A linear trend in the number of publications was observed (R^2 = 0.99) with a maximum of 25 records in 2022. The necessary virtualization of work and learning activities during the lockdowns put in the spotlight of the scientific community the effects of prolonged work in front of VDUs. The publishing areas are medicine (42.5%), health professions (10.5%), computer science (8.6%) and engineering (7.5%). India has contributed with 17.3% of the documents, the United States (17%), Spain (8.3%), China (5.1%), Saudi Arabia and the United Kingdom with 4.6%. In terms of institutions, four universities/research centers from Spain are in the Top-6, namely Universitat d'Alacant (1st), Universitat de València (4th), Universidad de Oviedo (5th) and Centro de Investigación Biomédica en Red de Epidemiología y Salud Pública (6th). The Top-6 is completed by the State University of New York (2nd) and the King Saud University (3rd).

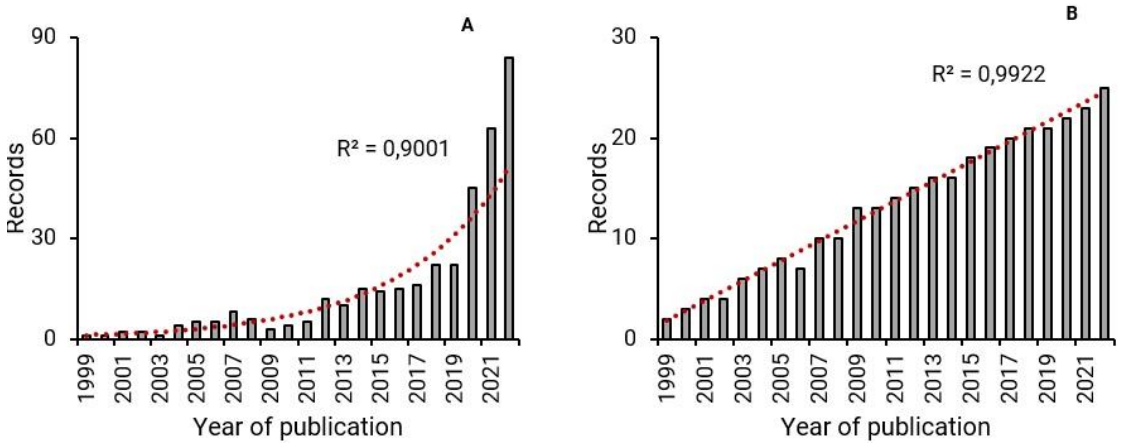

Fig. 4 – Evolution of the number of records on computer vision syndrome and digital eye strain indexed in the Scopus database. A: Records on computer vision syndrome (1999-2022); B: Records on digital eye strain (1999-2022).

The bibliometric network on CVS and digital eye strain is displayed in figure 5; indeed, both topics appear connected as the main clusters. As expected, COVID-19 and occupational health associated terms (ergonomics, risk factors, screen time and occupational health) appear as relevant. Also, some nodes related to CVS are associated to research on optometry like contact lenses, blink rate, asthenopia, accommodation, dry eye disease, visual fatigue, ocular surface and ocular symptoms. Several studies have investigated specific populations as students and children, observed also as nodes in figure 5.

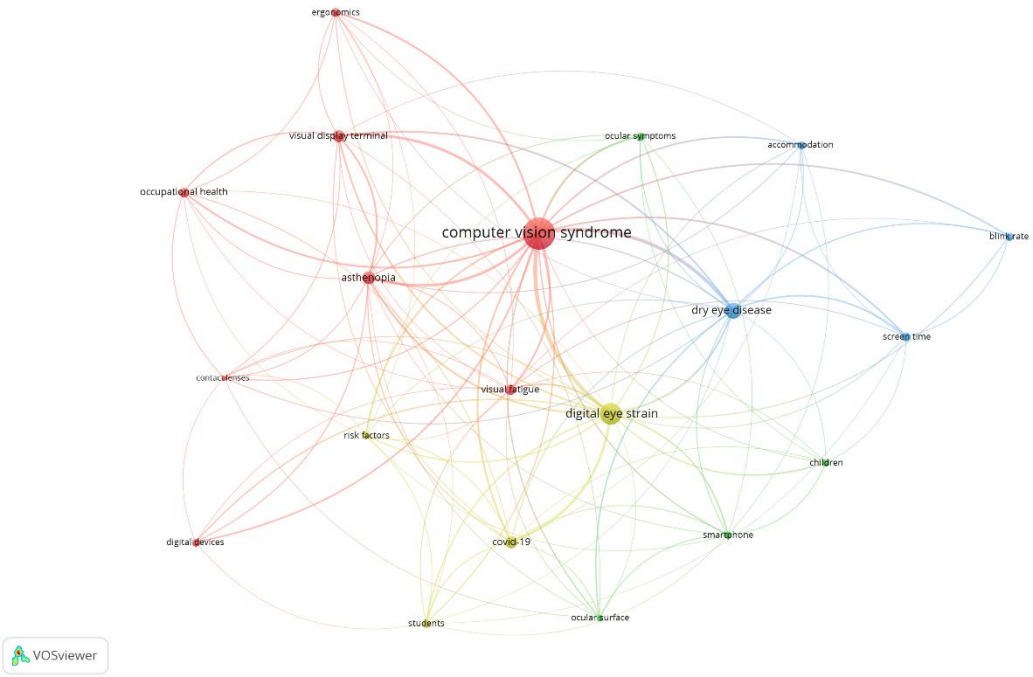

Fig. 5 – VOSviewer bibliometric network of most frequently mentioned author keywords on global output on computer vision syndrome and digital eye strain (minimum number of occurrences: 5).

Finally, terms associated to the devices (visual digital display, digital devices and smartphones) appear as relevant nodes. Despite this topic is certainly emergent and the scientific interest is still growing, some authors have contributed with several publications. A total of 4634 citations are counted in the topic and 35 documents have been cited at least 35 times (h-index = 35). The trend of citations

has substantially increased in the last 5 years; in 2018 only 313 citations in Scopus-indexed documents were counted, but in 2020 increased to 509, it doubled in 2021 to 1054 and by the Q4 of 2022 increased up to 1394. Table 1 presents the Top-10 of authors in the topic with their respective affiliation and h-index.

Table 1 - Summary of the most-cited documents in the topic of computer vision syndrome

Year	Document Title	Authors	Journal Title	Citations	Document type
2005	Computer vision syndrome: A review	Blehm C. *et al*	Survey of Ophthalmology	472	Review
2011	Computer vision syndrome: A review of ocular causes and potential treatments	Rosenfield M	Ophthalmic and Physiological Optics	297	Review
2018	Digital eye strain: Prevalence, measurement and amelioration	Sheppard AL, Wolffsohn JS	BMJ Open Ophthalmology	192	Review
2012	Computer-related visual symptoms in office workers	Portello JK, *et al*	Ophthalmic and Physiological Optics	142	Research
2016	Computer vision syndrome among computer office workers in a developing country: An evaluation of prevalence and risk factors	Ranasinghe P, *et al.*	BMC Research Notes	109	Research
2013	Blink rate, incomplete blinks and computer vision syndrome	Portello JK, *et al.*	Optometry and Vision Science	108	Research
2015	Computer vision syndrome: A review	Gowrisankaran S, Sheedy JE	Work	103	Review
2015	A reliable and valid questionnaire was developed to measure computer vision	Seguí-Crespo M, *et al.*	Journal of Clinical Epidemiology	102	Research

	syndrome at the workplace				
2008	Computer Vision Syndrome: A widely spreading but largely unknown epidemic among computer users	Yan Z, *et al.*	Computers in Human Behavior	100	Research
2019	Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know	Jaiswal S, *et al.*	Clinical and Experimental Optometry	99	Review

Table 2 shows the Top-10 of the most-cited papers in the topic. As observed in both tables, four of the most-cited papers have been first-authored by the three most influential authors in the topic.

Tabla 2 - Summary of the most-productive authors in the topic of computer vision syndrome

Author	Publications	h-index	Affiliation
Rosenfield M	13	32	Ophthalmic and Physiological Optics, SUNY College of Optometry
Portello JK	6	8	SUNY College of Optometry
Seguí-Crespo M	6	5	Universitat d'Alacant
García-Lázaro S	5	19	Universitat de València
Talens-Estarelles C	5	5	Universitat de València
Artime Ríos EM	4	3	Universitat d'Alacant
Jain E	4	7	Sadguru Netra Chikitsalaya
Mohan A	4	6	Global Hospital Institute of Ophthalmology
Sen P	4	6	Sadguru Netra Chikitsalaya
Shah C	4	6	Sadguru Netra Chikitsalaya

Table 3 shows the growth rate in the number of publications in the years 2016-2022. Regarding CVS and digital eye strain, there is a significant growth in 2020

with an increase of 104.3%. This coincides with the onset of the COVID-19 pandemic, which resulted in a massive increase in screen time due to remote work and distance education, also increasing the interest of the scientific community in the topic. In 2021, despite continued growth, the growth rate decreased to 42.6%, suggesting that while interest in the topic remains high, it has stabilized compared to the previous year. In 2022, the growth continues to decelerate to 36.1%, indicating a possible maturation of the topic in scientific literature.

In the case of telework, telecommuting, and remote work, an exponential growth of 300.9% was observed in 2020, reflecting the interest on remote work and its implications due to the drastic shift to this mode as part of the response to the COVID-19 pandemic. In 2021, although the growth decreased to 141.0%, it remained significantly high, suggesting continuity in the interest on investigating telework and its implications for the work force. In 2022, there was a decline in the growth rate with -6.0%, possibly due to a stabilization in the adoption of telework and a normalization of hybrid or in-person work practices, decreasing the short-term interest on the topic.

In terms of visual health, a notable decrease of -32.0% was observed in 2018, suggesting less attention to this topic before the pandemic. In 2019, a significant increase of 64.7% may be related to a growing interest prior to the pandemic, possibly due to an increasing recognition of the importance of visual health in the digital age. In 2020, growth remains at 14.3%, indicating that although the focus shifted to remote work, visual health continued to be an area of moderate interest. In 2021 and 2022, the growth rates are 18.8% and 13.2%, respectively, suggesting a steady but moderate interest in visual health. In contrast to the topics of CVS/digital eye strain and telecommuting/telework/remote work, there is no evidence that COVID-19 pandemic renewed the interest on visual health as major topic, showing the same growth trends in the period 2020-2022.

Tabla 3 - Growth rate of in the number of publications in the period 2016-2022

Topic	2022	2021	2020	2019	2018	2017	2016
CVS Digital eye strain	36.1%	42.6%	104.3%	4.8%	40.6%	11.6%	12.3%
Telework Telecommuting Remote work	-6.0%	141.0%	300.9%	20.4%	8.1%	-12.2%	30.7%
Visual health	13.2%	18.8%	14.3%	64.7%	-32.0%	19.0%	61.5%

Discussion

Telework stayed after COVID-19

The analysis of telework literature in the Scopus database revealed a substantial increase in publications, particularly in 2020-2021. This spike can be attributed to the global lockdowns and the subsequent shift to remote work as a response to the pandemic. The majority of these publications (63.2%) are research articles, highlighting the robust investigative efforts in understanding the implications and dynamics of telework. The dominance of social sciences (18.4%), computer science (14.3%), and business-related fields (12.4%) among these publications indicates a multidisciplinary interest, reflecting the complex interplay of technological, managerial, and social aspects inherent to remote work.

The co-occurrence analysis of keywords points to COVID-19 as a central node, highlighting the pandemic's role as a catalyst for research in telework/telecommuting. The sudden requirement to convert normally on-site activities, like office work and school classes, to remote activities mediated by virtual environments in all the countries applying total or partial lockdowns as consequence of COVID-19 have shown that many productive activities can be developed remotely just by applying some adaptations. Globally, 15% of employees referred to be working remotely before the COVID-19 pandemics.[4,5,13] This share increased to 74% during the strictest lockdown and, currently, 36% expect to be permanently working in a hybrid model.[4,5,13]

After the control of the pandemic and the economic reactivation the telework stayed for an important share of the workforce. Although telework implementation varies across productive sectors, it is intrinsically high in the knowledge- and ICT-intensive sectors where high-skilled employees and managers are already used to remote work.[4] This correlates with the geographical distribution of contributions, showing some of the more industrialized countries as the main contributors. The United States leads significantly with 32.9% of the total publications, followed by the United Kingdom, Canada, Japan, and Australia. This distribution may reflect the advanced digital infrastructure and the prevalence of knowledge-based industries in these countries, which facilitated a smoother transition to telework during the pandemic.

There are several factors to be considered when adopting the telework: individual factors, job factors, organizational factors, and family/home factors.[2] However, in the middle of an emergency there is no possibility to choose or adapt. The telework arrived as a quick response to the necessity to stay at home. It is evident that telework adoption is more natural for some economic sectors like the financial, commercial, educational, and services. In the case of manufacturing is appropriated for middle management levels, customer support, human resources management or marketing.[2] Therefore, it was expected that telework would remain in those sectors and areas after the end of pandemics.

Regarding those aspects, the authors' keywords co-occurrence related to communication and information technologies (ICT), digitalization, ergonomics, and mental and occupational health indicate those areas of focus in the telework research landscape. Although telework offered obvious advantages under the application of the social-distancing concept, as work becomes more virtual, there is also an increase in stress and workload, and consequently an impact in the workers well-being and performance.[14] Telework is often associated with increased workloads, since organizations sometimes raise their performance expectations under the assumption of higher efficiencies because of the use of ICTs. Moreover, physical offices provide a tangible boundary between work and private life, limiting the degree of interference of one into each other but this

boundary fades when work takes place at home.[14] In many cases the presence of a workspace in the home facilitates to stay long hours connected through the ICTs, in addition to organizational expectations of constant connectivity and extended availability even out of office hours.[14,15]

Recent studies carried out in the context of the COVID-19 pandemics shown increased workload and technostress as consequence of difficult control of remote working.[6,16] All those situations are not limited to work, are also valid to the virtual educational environments, in which students must spend a lot of time online attending classes and doing homework, all mediated by ICTs. Ergonomic hazards derived from sedentarism, execution of repetitive movements, incorrect and prolonged postures, may lead to musculoskeletal system disorders and may increase the risk of obesity and diabetes.[6] The mental health issues faced by remote workers include excessive workloads and stress, anxiety, depression, anger, self-isolation and insomnia, among others.[6]

Effects of VDUs on visual health

The second bibliometric search focusing on visual health revealed an exponential increase in publications since the early 2000s, with a notable rise in the past five years with a notable spike between 2020-2022. The adoption of telework and virtual education during and beyond the COVID-19 emergency has led to higher levels of exposure of the visual system to VDUs, increasing also the potential risks associated. Furthermore, it has been established that companies implement the usual occupational health and safety strategies in teleworking, without differentiating the risks and the nature linked to the work modality. It is worth noting that during the pandemic neither the insurers nor the government have deployed prevention campaigns, specific policies or hygiene recommendations different from those implemented in the on-site work, even though the work modality and risk matrix changed completely.

The United States again leads in contributions (31%), followed by China, the United Kingdom, Spain, and Canada. The prominent areas of publication include medicine

(38.3%), health professions (6.8%), and engineering (6.6%), indicating a strong medical and technical research focus in this field. The keyword co-occurrence network for visual health reveals significant clusters around COVID-19, various eye pathologies and issues related to the prolonged use of VDUs such as visual fatigue and asthenopia. This highlights the immediate concerns related to increased screen time and its impact on visual health during the pandemic.

In the last two decades, the exponential growth in the use VDUs present in mobile devices, tablets, laptops and others, has sparked the interest of health professionals, especially vision experts, warning about the effects of excessive use of those devices.[17,18] Modern VDUs are light-emitting diodes (LED) screens with a radiation peak in the short-wavelength region. Therefore, the light emitted by VDUs have proportionally a high composition of blue (610-670 THz) and violet 670-750 THz) light, i.e., those with the highest frequency in the visible spectrum, close to more dangerous ultraviolet radiation. Long-time exposure to VDUs has correlated with negative effects on eye due to proximity and extended use, thus leading to a set of ocular and vision alterations, which include discomfort, near vision stress disorder and asthenopic symptoms.[17,18] Among the most characteristic symptoms are eye strain, irritates eyes, blurred vision, red eyes, burning eyes, light sensitivity, excessive tearing, diplopia, headache, and slowness in changing to different focus.[19,20]

It has been demonstrated that continued use of computers affects both blink rate and amplitude, as well as tear stability. The dry eye syndrome appears as the most common ocular alteration during long work periods associated to increased corneal exposure to light and low blinking frequency.[21,22] The over-exposure to those factors results in an increased rate of tear evaporation leading to specific symptomatology such as burning, grittiness sensation, eye redness, excessive tearing irritates eyes, and, in some cases, corneal surface irregularities as corneal ulcer might occur.[21] Although, the effects of smartphones on blink rate are inconclusive due to the still low number of studies in the field, the consequences are expected to be like the observed with computers and tablets, since the task difficulty would contribute to reduce the blink rate.[22]

The literature also refers to a clear relationship between the use of VDUs (computers, smartphones and tablets) and ocular and visual symptoms such as headaches, eyestrain, dry eyes and sore eyes; all together configure the CVS. This near-vision stress disorder is linked to symptoms like blurred vision, double vision, slowness in changing focus and headache. The near vision demands when using digital screens causes non-strabismic binocular dysfunctions as accommodative and vergence alterations, affecting both binocular vision and visual performance.[23] The accommodative dysfunctions such as accommodative excess, accommodative infacility, paralysis and spasm of accommodation appear more frequently as consequence of near vision over work. The most common is the accommodative excess, in which the subject exerts more accommodation and closer focus than the required. In the long term, such over-accommodation may produce an inability to focus independently of distance causing an accommodative spasm due to the over-contracture of the ciliary muscle. Furthermore, those non-strabismic binocular dysfunctions are accompanied by vergence alterations like exo and esophoria. Exophoria occurs as a consequence of convergence insufficiency caused by an inability to focus on any distance. In contrast, esophoria occurs when the subject is unable to relax the accommodation producing an excess of convergence due to over-focus in the near distance. Apart from accommodative excess, the accommodative infacility or inertia consists of slowness to change the focus from one level to another, causing blurred distance vision or difficulty to relax the accommodation immediately after performing near-vision tasks.

Increase of the prevalence of CVS symptoms due to prolonged use of VDUs

The specific focus on CVS and digital eye strain shows a steady increase in interest, particularly significant during the pandemic years. The rise in publications from 14 papers per year (2011-2019) to a doubling in 2020 and another doubling by 2022 emphasizes the intensification of the interest on this topic, as remote work and learning became ubiquitous. This trend is likely linked to the expected increase on

the prevalence of visual pathologies due to the extended use of VDUs by the shift to remote work and online learning during and after the pandemics.

India, the United States, and Spain are the top contributors, with notable institutional contributions from Spanish universities, which has an important number of institutions dedicated to the field of optometry. The networks analysis reveals significant clusters around terms such as "COVID-19," "occupational health" and "screen time," reflecting the immediate relevance of these factors in the context of the pandemic. Medicine leads as the primary field of publication (42.5%), followed by health professions (10.5%). In this regard, the recent literature referred several cross-sectional studies that have shown that the e-learning strategies implemented during the COVID-19 lockdowns increased the prevalence of CVS in all levels of education.[24,25,26] It has been reported that digital devices affect the accommodative system and binocular vision in pre-teens, indicating significant vergence disorders in children with severe CVS.[27]

It was also frequent the complaints about ocular symptoms in children studying under virtual modality during the lockdown, especially when the exposition time is longer than 6 hours, leading to a prevalence of all CVS symptoms higher than 50%.[28,29] Thus, the severity of the symptoms correlates with the number of hours of using digital devices; moreover, when time of exposition to VDUs increased up to 40% over the usual time before the pandemics.[29] In adults, the prevalence of symptoms might be higher since they are required to stay longer due to their responsibilities either in university education, work, or even, both. This prevalence has been reported to be over 60% for more than one symptom associated to CVS.[7]

There are some conditions which increase the prevalence of CVS such as the time spent per day, the posture adopted, length of use, level of light, vision disorders, age and even gender, since higher prevalence has been associated to female population.[7,28,29] Also, working in front of VDUs under low light levels increase the risk of eye fatigue in 1.72; furthermore, the use of VDUs at short distance (less than the arm length) might increase the severe CVS symptoms.[7,28,29]

The bibliometric analysis highlighted the growth and evolving focus of research in telework, visual health, and CVS, driven by the global response to the COVID-19

pandemic. This shift not only reflects the immediate need to adapt to new working conditions but also sets the stage for ongoing investigations into the long-term implications of these changes on health and productivity. Nevertheless, given the number of publications, the CVS is still an emerging topic in optometry and ophthalmology. The accumulated scientific evidence regarding the impact of screens on vision is still limited and further research is required since the use of different digital devices is highly heterogeneous, due to the penetration on population of all ages, different screen sizes in the market, variable working distance, indoor and outdoor usage, simultaneous and multiple use of devices. The bibliometric trends suggest that the COVID-19 pandemic significantly influenced research directions in both telework and visual health. The rapid adaptation to remote work environments necessitated by lockdowns has motivated research into the benefits, challenges, and long-term implications of telework/telecommuting. Concurrently, the increased screen time associated with telework and online education put the focus on concerns about visual health, particularly CVS and digital eye strain. On the other hand, the negative effects of blue-light radiation on photosensitive cells and an increased prevalence of myopia remain controversial issues that require more experimental and observational evidence.

The findings suggest a need for continued multidisciplinary research to address the evolving challenges of telework and its impact on visual health. The symptoms associated with the CVS became an everyday situation for students and workers around the world during the COVID-19 pandemics lockdowns. The adoption of teleworking and virtual education strategies in the context of the restrictive measures increased the exposition to the visual display units and, in the post-pandemics the participation of telework and virtualization intensified, since they allow rationalization of costs, infrastructure and environmental impacts. This context motivates deeper investigations into the impacts of such changes in occupational health. This includes exploring effective ergonomic solutions, developing digital tools to mitigate adverse health effects, and understanding the broader social and psychological implications of prolonged remote work environments.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contribution

Conceptualization: David Gómez-Ríos.

Data curation: Paula Pérez-Espinel, Howard Ramírez-Malule and David Gómez-Ríos.

Formal analysis: Paula Pérez-Espinel, Howard Ramírez-Malule and David Gómez-Ríos.

Funding acquisition: Howard Ramírez-Malule and David Gómez-Ríos.

Investigation: Paula Pérez-Espinel, Howard Ramírez-Malule and David Gómez-Ríos.

Methodology: Howard Ramírez-Malule and David Gómez-Ríos

Project administration: David Gómez-Ríos.

Resources: Howard Ramírez-Malule and David Gómez-Ríos.

Supervision: David Gómez-Ríos.

Validation: Howard Ramírez-Malule and David Gómez-Ríos.

Software: Howard Ramírez-Malule and David Gómez-Ríos

Visualization: Howard Ramírez-Malule and David Gómez-Ríos.

Writing – original draft: Paula Pérez-Espinel and David Gómez-Ríos.

Writing – proofreading and editing: Howard Ramírez-Malule and David Gómez-Ríos.