Magna Scientia UCEVA

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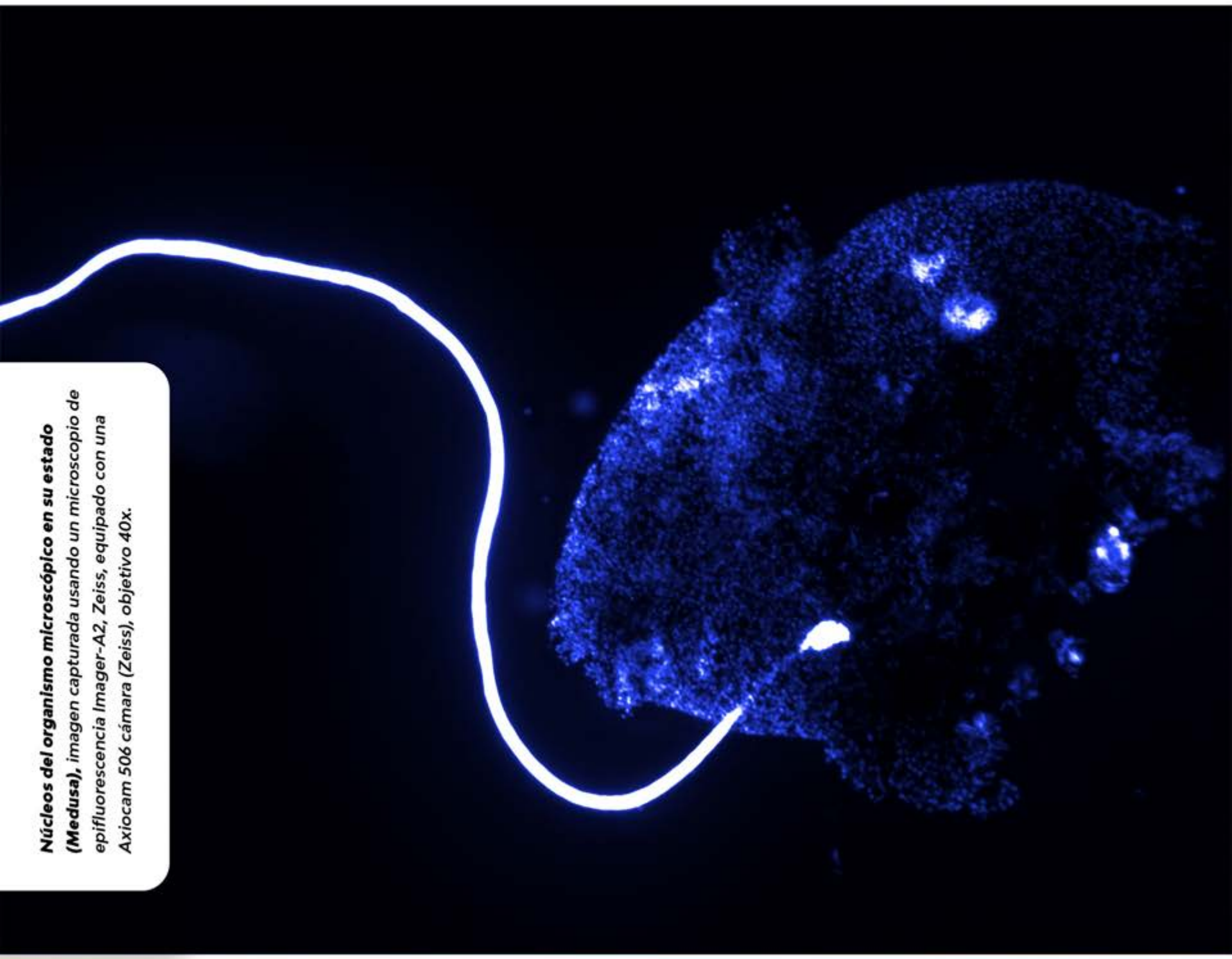

Núcleos del organismo microscópico en su estado (Medusa), *imagen capturada usando un microscopio de epifluorescencia Imager-A2, Zeiss, equipado con una Axiocam 506 cámara (Zeiss), objetivo 40x.*

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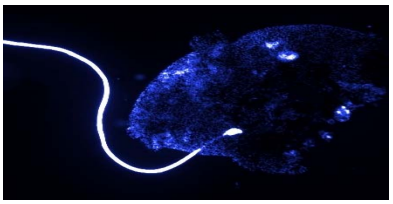

Créditos fotografía: David Velásquez Carvajal, PhD.
Descripción: Imágen microscópica de plancton (medusa). La muestra fue tomada en el mar Mediterráneo, en el lugar Ville-franche-sur-mer, Francia; se fijó con paraformaldehído y su tinción fue con Hoechst, por lo tanto, lo que se ve son los núcleos del organismo microscópico en su estado. La imagen fue capturada usando un microscopio de epifluorescencia Imager-A2, Zeiss, equipado con una Axiocam 506 camera (Zeiss), objetivo 40x.

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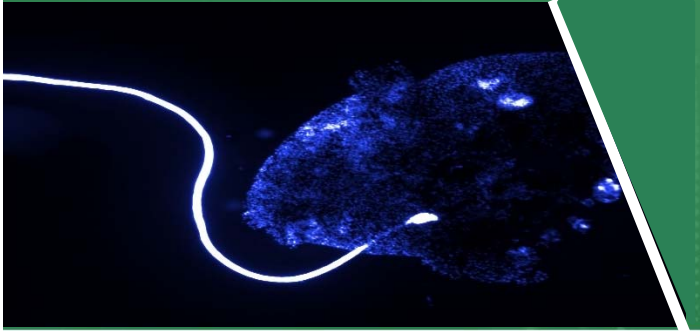

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Editorial

Tercera edición, primeras indexaciones

Third edition, first indexation

Juan Carlos Urriago Fontal, PhD.

La trascendencia internacional de nuestra revista científica, Magna Scientia UCEVA, se ha consolidado de manera ineludible gracias a su reciente inclusión en dos de los índices más respetados a nivel global: LATINDEX y DOAJ. Esta conquista no solo se erige como un hito en nuestro camino, sino que también representa un contundente avance hacia la expansión de la visibilidad de nuestra publicación científica a nivel mundial. De manera intrínseca, esta distinguida inclusión proyecta sus luces sobre la UCEVA, como entidad editora, inscribiéndola en el escenario internacional como un referente en la producción y difusión de conocimiento.

En su esencia, esta prestigiosa mención en los índices **LATINDEX y DOAJ** no solamente corrobora, sino que reafirma enérgicamente la calidad y pertinencia de nuestro quehacer académico. Dicha validación aporta una capa adicional de credibilidad, resaltando la meticulosa labor de nuestros investigadores y el riguroso proceso de revisión por el que cada artículo es sometido. Esta resonante certificación también abona al valor de las contribuciones de nuestros autores, elevando sus esfuerzos a la esfera internacional y subrayando su participación en la creación de un cuerpo de conocimiento global.

La trascendencia de citar los artículos contenidos consagradamente en las páginas de Magna Scientia UCEVA, se sitúa en el epicentro de la amplificación del impacto de la investigación. Al hacerlo, no solo honramos el esfuerzo y la tenacidad de los autores, sino que también contribuimos al tejido mismo de la indagación científica, al permitir que otros eruditos avancen en sus propias exploraciones, cimentando un ciclo de crecimiento intelectual interconectado. No obstante, es relevante subrayar que este proceso trasciende la mera enumeración de referencias; al citar correctamente, erigimos pilares de integridad y autenticidad en la labor investigativa, cultivando una senda de excelencia y rigurosidad en la producción científica que reverbera en toda la comunidad académica.

The international transcendence of our scientific journal, Magna Scientia UCEVA, has been inescapably consolidated thanks to its recent inclusion in two of the most prestigious global indexes: LATINDEX and DOAJ. This achievement is not only a milestone in our journey, but also an important step towards increasing the visibility of our scientific publications throughout the world. In itself, this prestigious inclusion highlights the UCEVA as a publishing entity and places it on the international scene as a benchmark in the production and dissemination of knowledge.

In essence, this prestigious mention in the LATINDEX and DOAJ indexes not only confirms, but strongly reaffirms the quality and relevance of our academic work. This validation provides an additional layer of credibility, highlighting the meticulous work of our researchers and the rigorous review process that each article undergoes. This resounding certification also adds value to the contributions of our authors, elevating their efforts to an international level and underlining their participation in the creation of a global body of knowledge.

The importance of citing the articles contained within the pages of Magna Scientia UCEVA lies at the epicentre of amplifying the impact of research. In doing so, we not only honour the effort and tenacity of the authors, but also contribute to the fabric of scientific inquiry itself, enabling other scholars to further their own explorations and cementing a cycle of interrelated intellectual growth. It is important to stress, however, that this process goes beyond the mere listing of references; by citing correctly, we build pillars of integrity and authenticity in research work, cultivating a path of excellence and rigour in scholarly production that reverberates throughout the academic community.

La presentación de esta tercera edición constituye un sólido testimonio de nuestra inquebrantable dedicación a la promoción de la investigación y la entrega de una educación de excelencia. Nuestra misión se extiende más allá de los confines convencionales, ya que aspiramos a erigir un entorno que no solo nutra la chispa de la creatividad, sino que también alimente los fuegos de la innovación en cada rincón del vasto territorio científico. En este sentido, la publicación que hoy contemplamos se erige como un fiel reflejo de esta noble ambición. Al alentar el florecimiento de las ideas más vanguardistas, anhelamos que esta edición no solo emule, sino que trascienda el impacto logrado por sus predecesoras.

La relevancia de Magna Scientia UCEVA trasciende las fronteras de nuestra institución, extendiendo sus alas como una herramienta inestimable tanto para los estudiantes que buscan expandir su comprensión, como para los docentes e investigadores que exploran los límites del conocimiento. Al aspirar a este impacto global, ambicionamos que esta revista se erija en una fuente inagotable de inspiración, que ilumine el camino de las generaciones presentes y venideras de científicos e investigadores. En virtud de esto, quisiera subrayar la relevancia de no solo citar las obras plasmadas en las páginas de Magna Scientia UCEVA, sino de internalizar la identidad institucional que esta publicación simboliza.

Cada referencia a los artículos aquí contenidos no solo honra a los individuos detrás de las palabras, sino que también rinde homenaje a nuestra entidad educativa y a su firme compromiso con la búsqueda incesante de la excelencia académica. A través de estas citas, no solo otorgamos crédito a la minuciosa labor de los autores, sino que también celebramos la devoción que nuestra institución profesa hacia la investigación rigurosa y la colaboración global. Con cada mención de Magna Scientia UCEVA, elevamos la bandera de la investigación distintiva y reafirmamos nuestra determinación de propiciar oportunidades formativas para los estudiantes, así como de tejer redes académicas que trasciendan fronteras.

El tercer volumen se inicia con una contribución significativa de dos investigadores con una amplia experiencia en el ámbito médico, Avinash Pujari y Prashant Kamath, que están afiliados a la institución MIMER Medical College, ubicada en Talegaon Dabhade, Pune, India.

The launch of this third edition is a powerful testimony to our unwavering commitment to the advancement of research and the provision of excellence in education. Our mission goes beyond conventional boundaries, as we strive to create an environment that not only nurtures the spark of creativity, but also fuels the fires of innovation in every corner of the vast scientific territory. In this sense, the publication before us today is a true reflection of this noble ambition. By encouraging the blossoming of cutting-edge ideas, we hope that this issue will not only emulate but surpass the impact of its predecessors.

The relevance of Magna Scientia UCEVA transcends the boundaries of our institution, spreading its wings as an invaluable tool for students seeking to broaden their understanding, as well as for teachers and researchers exploring the frontiers of knowledge. As we strive for this global impact, it is our ambition that this journal will serve as an inexhaustible source of inspiration, illuminating the path of present and future generations of scholars and researchers. In this sense, I would like to emphasise the importance of not only citing the works published in the pages of Magna Scientia UCEVA, but also of internalising the institutional identity that this publication symbolises.

Each reference to the articles contained herein not only honours the individuals behind the words, but also pays tribute to our institution and its unwavering commitment to the relentless pursuit of academic excellence. Through these citations, we not only recognise the painstaking work of the authors, but also celebrate our institution's dedication to rigorous research and global collaboration. With each Magna Scientia UCEVA citation, we raise the banner of distinctive research and reaffirm our determination to foster formative opportunities for students and to weave academic networks that transcend borders.

The third volume opens with a major contribution from two researchers with extensive experience in the medical field, Avinash Pujari and Prashant Kamath, who are associated with the MIMER Medical College in Talegaon Dabhade, Pune, India.

Este estudio llevado a cabo por estos investigadores indios tenía como objetivo evaluar tanto la precisión como el grado de cumplimiento de las directrices internacionales en lo que respecta a la certificación médica de la causa de muerte. Este análisis se centró en un centro de atención terciaria en la región rural de Maharashtra occidental, India.

Además de evaluar la certificación médica, el estudio identificó errores y discrepancias comunes, así como investigó los factores que influyen en el proceso de certificación médica dentro de este centro. El propósito subyacente de esta investigación era obtener una comprensión exhaustiva de la exactitud en la documentación de las causas de muerte, y, más importante aún, contribuir a mejorar el cumplimiento de las prácticas estandarizadas en este aspecto crucial de la práctica médica.

Acto seguido, presentamos la primera contribución de la UCEVA: "El papel determinante de la genética y el estilo de vida en la dismenorrea". Este exhaustivo análisis es obra del Dr. Ángel Alfonso Aguirre Durán, de la Facultad de Ciencias de la Salud, en colaboración con la enfermera Natalia Martínez Arias. Además, cuenta con la colaboración de la respetada autora Celia Diez de los Ríos de la Serna, de la Universidad de Barcelona, España, quien ya había enriquecido nuestro volumen anterior en 2022. También se suma a esta distinguida lista la eminente científica peruana Mev Dominguez Valentin, actualmente vinculada al Instituto de Investigación en Cáncer del Hospital Universitario de Oslo, Noruega.

En este artículo, los investigadores abordan de manera integral el desafío de la dismenorrea, explorando la interacción entre los genes de susceptibilidad relacionados con este trastorno y el impacto del estilo de vida de los pacientes, incluyendo su dieta, hábitos y niveles de estrés. Los autores resaltan los avances significativos que se han logrado en este campo, adoptando una perspectiva constructiva, y delimitan las futuras direcciones que deben seguirse en la investigación de esta afección. La dismenorrea, ya sea como trastorno primario o secundario, representa una de las principales causas de incapacidad, tanto parcial como total, en el ciclo vital de la mujer. Este problema afecta no solo a las mujeres en edad reproductiva, sino también a aquellas en etapas posteriores de su vida.

The study conducted by these Indian researchers aimed to assess both the accuracy and the degree of compliance with international guidelines on medical certification of cause of death. The analysis focused on a tertiary care centre in rural western Maharashtra, India.

In addition to evaluating medical certification, the study identified common errors and discrepancies and investigated factors influencing the medical certification process at this centre. The underlying aim of this research was to gain a comprehensive understanding of the accuracy of cause of death documentation and, more importantly, to help improve adherence to standardised practice in this crucial aspect of medical practice.

We then present the first UCEVA paper: "The determining role of genetics and lifestyle in dysmenorrhoea". This in-depth analysis is the work of Dr Ángel Alfonso Aguirre Durán, from the Faculty of Health Sciences, in collaboration with nurse Natalia Martínez Arias. It also has the collaboration of the prestigious author Celia Diez de los Ríos de la Serna, from the University of Barcelona, Spain, who had already enriched our previous volume in 2022. The prestigious Peruvian scientist Mev Dominguez Valentin, currently at the Institute of Cancer Research at Oslo University Hospital in Norway, also joins this prestigious list.
In this article, researchers take a comprehensive approach to the challenge of dysmenorrhoea, exploring the interplay between the susceptibility genes associated with this disorder and the impact of the patient's lifestyle, including diet, habits and stress levels.

From a constructive perspective, the authors highlight the significant advances that have been made in the field and outline future directions for research into this condition. Dysmenorrhoea, whether primary or secondary, is one of the main causes of partial or total disability in the female life cycle. This problem affects not only women of reproductive age, but also those in later life.

La tercera contribución en este tercer volumen se titula ***"Efectividad de las intervenciones educativas en la reducción de infecciones asociadas a la atención médica en la unidad de cuidados intensivos para adultos: una revisión de alcance".*** Este artículo proviene de autores de la Universidad Santiago de Cali-USC, Cali, Colombia, y se propone un objetivo claro: evaluar a fondo la efectividad de las intervenciones educativas destinadas a reducir las infecciones asociadas a la atención médica (IAAS) en la unidad de cuidados intensivos (UCI) de adultos.

Los estudios que sirvieron como base para esta exhaustiva revisión de alcance arrojaron un hallazgo crucial: la educación emerge como un componente esencial, cuyo impacto se extiende a todos los niveles, desde los equipos multidisciplinarios de atención hasta los pacientes, sus familias y los cuidadores. Además, es digno de resaltar que dos de estos estudios demostraron una significativa reducción en las IAAS, respaldando aún más la importancia de la educación como una herramienta efectiva.

A pesar de la considerable variabilidad en cuanto a la duración y el enfoque de las intervenciones educativas, este análisis subraya la necesidad crítica de establecer una educación continua, ya que esta se revela como un factor clave para mantener los resultados de la intervención y lograr mejoras concretas en los resultados clínicos. En resumen, este estudio nos recuerda la esencial importancia de la educación como una herramienta poderosa en la lucha contra las IAAS en entornos críticos como las UCIs de adultos.

Posteriormente, presentamos el revelador estudio de investigación titulado "***Diagnóstico de la enfermedad de Wilson y sus fenotipos mediante inteligencia artificial***", cuya autora de correspondencia es la destacada Dra. Cecilia Giulivi, científica de renombre de la Universidad de Davis en California, Estados Unidos. Este estudio aporta hallazgos de suma relevancia, los cuales tienen un impacto profundo en la formulación de terapias dirigidas y en la optimización de enfoques dietéticos para el tratamiento de pacientes que padecen la Enfermedad de Wilson (EW).

Los enfoques dietéticos destinados a abordar la EW deben enfocarse en la reducción de la sobrecarga en el ciclo de la urea y, por ende, en la disfunción mitocondrial, al mismo tiempo que garantizan una

The third paper in this third volume is entitled ***"Effectiveness of educational interventions in reducing healthcare-associated infections in the adult intensive care unit: a scoping review".*** This article, by authors from the Universidad Santiago de Cali-USC, Cali, Colombia, has a clear objective: to thoroughly evaluate the effectiveness of educational interventions aimed at reducing healthcare-associated infections (HAIs) in the adult intensive care unit (ICU).

The studies that formed the basis of this comprehensive scoping review produced a key finding: education emerges as an essential component, with an impact at all levels, from multidisciplinary care teams to patients, their families and carers. Notably, two of these studies demonstrated a significant reduction in HAIs, further supporting the importance of education as an effective tool.

Despite considerable variability in the duration and focus of educational interventions, this analysis underscores the critical need for ongoing education, as this proves to be a key factor in sustaining intervention results and achieving concrete improvements in clinical outcomes. In conclusion, this study reminds us of the fundamental importance of education as a powerful tool in the fight against HAIs in critical settings such as adult ICUs.

Next, we present the enlightening research study entitled: ***"Diagnosis of Wilson's disease and its phenotypes using artificial intelligence",*** whose corresponding author is the prominent Dr Cecilia Giulivi, a renowned scientist at the University of Davis in California, USA. This study provides highly relevant findings that will have a profound impact on the formulation of targeted therapies and the optimisation of dietary approaches for the treatment of patients suffering from Wilson's disease (WD).

Dietary approaches to WD should focus on reducing urea cycle overload and thus mitochondrial dysfunction, while ensuring adequate protein intake

ingesta proteica adecuada para minimizar la sarcopenia asociada con la hipertensión portal. Vale la pena destacar que el ajuste de la proporción entre BCAA/AAA, una estrategia que ha sido ampliamente investigada en el tratamiento de la encefalopatía hepática, puede demostrar ser particularmente valioso en casos de EW donde coexisten manifestaciones hepáticas y neurológicas. En conjunto, este estudio destaca la importancia de considerar enfoques dietéticos y terapéuticos específicos para abordar de manera efectiva la complejidad de la Enfermedad de Wilson.

La segunda y última contribución de la UCEVA, siguiendo las directrices de MinCiencias-Colombia para evitar la endogamia editorial, proviene de la enfermera y PhD. Paola Andrea Fontal Vargas. En su trabajo de tesis doctoral en la Universidad Nacional de Colombia, en colaboración con su tutora, la profesora emérita Renata Virginia González Consuegra, nos presentan un artículo de reflexión titulado "***Beneficios de la actividad física en el tratamiento de la insuficiencia cardíaca***". Este artículo evidencia que las intervenciones de enfermería desempeñan un papel fundamental en la mejora del conocimiento, los comportamientos y la reducción de reingresos hospitalarios en pacientes con esta condición. Además, destaca la recomendación de la actividad física aeróbica no solo como medida preventiva, sino como un factor clave para mejorar la calidad de vida de los pacientes con enfermedades crónicas, incluida la insuficiencia cardíaca.

Esta reflexión aborda la importancia de la cultura de la actividad física y sus beneficios en pacientes con enfermedades crónicas, como la insuficiencia cardíaca. El ejercicio físico se ha demostrado como un elemento que contribuye significativamente a aliviar los síntomas y a elevar la autoestima en estos pacientes. La insuficiencia cardíaca imposibilita a menudo una vida plena debido a los diversos síntomas que conlleva, pero la evidencia científica respalda de manera sólida la prescripción de la actividad física como un componente integral en el tratamiento de esta afección.

La destacada primera sesión de la revista, centrada en el ámbito de las ciencias de la salud, culmina con una investigación liderada por la docente investigadora Olga Lucia Gaitán-Gómez, Ph.D., de la Universidad Libre, seccional Cali, Colombia, junto con sus coauto-

to minimise sarcopenia associated with portal hypertension. It is worth noting that adjusting the BCAA/AAA ratio, a strategy that has been extensively studied in the treatment of hepatic encephalopathy, may prove particularly valuable in cases of WD where hepatic and neurological manifestations coexist. Overall, this study highlights the importance of considering specific dietary and therapeutic approaches to effectively address the complexity of WD.

The second and final contribution from the UCEVA, in line with MInCiencias-Colombia's policy of avoiding editorial inbreeding, comes from the nurse and doctoral candidate Paola Andrea Fontal Vargas. In her doctoral thesis at the National University of Colombia, in collaboration with her supervisor, Professor Emeritus Renata Virginia González Consuegra, she presents us with a thought-provoking article entitled ***"Benefits of physical activity in the treatment of heart failure".*** This article shows that nursing interventions play a fundamental role in improving knowledge and behaviour and reducing hospital readmissions in patients with this condition.

It also highlights the recommendation of aerobic physical activity not only as a preventive measure, but as a key factor in improving the quality of life of patients with chronic diseases, including heart failure.

This reflection focuses on the importance of the culture of physical activity and its benefits for patients with chronic diseases such as heart failure. Exercise has been shown to make a significant contribution to alleviating symptoms and improving self-esteem in these patients. Heart failure often prevents people from living a full life due to the range of symptoms it causes, but scientific evidence strongly supports the prescription of physical activity as an integral part of the management of this condition.

The journal's outstanding first session, which focuses on the field of health sciences, culminates with research led by Research Professor Olga Lucia Gaitán-Gómez, PhD. of the Universidad Libre, Cali, Colombia, and her co-authors.

ras. Este estudio se enfoca en evaluar la tasa de graduación de un programa de enfermería y en explorar los factores que influyen en el éxito o fracaso de la finalización del programa.

La investigación adoptó un enfoque descriptivo, utilizando una muestra de estudiantes matriculados y graduados en un programa de enfermería en una universidad del suroccidente de Colombia, en el período comprendido entre 2012 y 2021. Los datos para el estudio se recopilaron de los registros académicos de la universidad, se organizaron meticulosamente y se analizaron mediante hojas de cálculo en Microsoft Excel®. El proceso analítico incluyó un detallado análisis estadístico descriptivo, que abarcó tablas de frecuencia, índices y proporciones. Es relevante señalar que se dieron los debidos cumplimientos éticos en el estudio, con la aprobación formal del Comité de Ética de la Facultad de Salud, como se documenta en el Acta No. 05 del 22 de abril de 2022. La tasa de graduación acumulada para el programa de enfermería durante el período 2017-2021 se situó en un 37.9%.

La sesión de Bioquímica, Genética y Biología Molecular se inicia con una destacada colaboración entre la Universidad Nacional de Colombia, campus Palmira, y un equipo brasileño. Su estudio, titulado "Genotipificación de introducciones de *Capsicum chinense* Jacq. mediante marcadores moleculares SSR fluorescentes", revela la aplicación exitosa de marcadores SSR fluorescentes para identificar genotipos élite con una amplia variabilidad genética en muestras de *C. chinense*.

Esta estrategia, diseñada con la visión de futuras certificaciones de origen geográfico en programas de mejoramiento, promete transformar las estrategias de selección en el campo del Fitomejoramiento. Los marcadores SSR fluorescentes han proporcionado una visión más completa y detallada de la diversidad genética en las poblaciones estudiadas, superando las limitaciones de las técnicas convencionales. Los resultados han arrojado una rica variedad de perfiles genéticos, validando la eficacia de estos marcadores para diferenciar genotipos que pueden compartir similitudes morfológicas pero que exhiben diferencias genéticas significativas. La incorporación de esta estrategia en programas de Fitomejoramiento representa una apertura hacia la creación de cultivares notablemente mejorados.

This study focuses on evaluating the completion rate of a nursing programme and exploring the factors that influence success or failure in completing the programme.

The research adopted a descriptive approach, using a sample of students enrolled in and graduating from a nursing programme at a university in south-western Colombia between 2012 and 2021. Data for the study were collected from the university's academic records, meticulously organised and analysed using Microsoft Excel® spreadsheets. The analytical process included a detailed descriptive statistical analysis, including frequency tables, indices and proportions. It is important to note that the study was ethically compliant, with formal approval from the Ethics Committee of the Faculty of Health, as documented in Minutes No. 05 of 22 April 2022. The cumulative graduation rate of the nursing programme for the period 2017-2021 was 37.9%.

The Biochemistry, Genetics and Molecular Biology session opens with an outstanding collaboration between the Universidad Nacional de Colombia, Palmira campus, and a Brazilian team. Their study, entitled ***"Genotyping of Capsicum chinense Jacq. introductions using fluorescent SSR molecular markers",*** shows the successful application of fluorescent SSR markers to identify elite genotypes with high genetic variability in C. chinense samples. This strategy, developed with a view to future certification of geographical origin in breeding programmes, promises to transform selection strategies in plant breeding. Fluorescent SSR markers have provided a more complete and detailed picture of the genetic diversity in the populations studied, overcoming the limitations of conventional techniques.

The results have yielded a rich diversity of genetic profiles, confirming the effectiveness of these markers in differentiating genotypes that may share morphological similarities but exhibit significant genetic differences. The incorporation of this strategy into breeding programmes opens the door to the creation of significantly improved varieties.

La identificación de genotipos élite con una amplia variabilidad genética marca el inicio de la generación de variedades con características innovadoras en términos de productividad y calidad de los frutos.

La sesión de Ciencias Ambientales se abre con un estudio de la Universidad Autónoma de Chiapas, México, titulado: ***"Sustentabilidad Ambiental Universitaria: Estrategias y Percepciones en la UNACH - Un Estudio de Caso".*** Este estudio tiene como objetivo identificar y analizar las estrategias y acciones que respaldan la educación ambiental y la percepción de la comunidad universitaria con respecto a la cultura ambiental promovida en la Escuela de Ciencias Administrativas Campus Arriaga de la Universidad Autónoma de Chiapas-México.

El enfoque de la investigación es descriptivo, basado en un estudio de caso que se construye sobre tres fuentes de información clave: documentos institucionales, proyectos de investigación o extensión, y entrevistas con miembros de la comunidad universitaria. A través de 37 entrevistas con docentes, directivos, administrativos y estudiantes, se exploró la percepción sobre el tema ambiental.

Los resultados revelan la presencia de ocho unidades de competencia centradas en el tema ambiental en los programas de Contaduría y Administración. Además, se han implementado 23 acciones a largo plazo entre 2011 y 2023, junto con cinco proyectos de investigación y cuatro productos académicos relacionados con el ámbito ambiental. Estos hallazgos confirman que los participantes perciben que ambos programas educativos están comprometidos en fortalecer la cultura ambiental. En resumen, la investigación demuestra que las funciones sustantivas y las acciones intrauniversitarias impactan positivamente en la apropiación de la cultura ambiental entre la comunidad universitaria, y que la Escuela se enfoca en la formación integral con un alto sentido de responsabilidad y conciencia ambiental.

Desde España, nuestra siguiente contribución marca la apertura de la sesión de Ciencias Biológicas y Agrícolas con un artículo de investigación original titulado "Indicadores para la Transición Agroecológica: Seguridad Alimentaria, Nutrición, Bienestar y Promoción de un Modelo Alimentario Sostenible". Este estudio destaca la necesidad de

The identification of elite genotypes with high genetic variability marks the beginning of the generation of varieties with innovative characteristics in terms of productivity and fruit quality.

The Environmental Sciences session will open with a study from the Autonomous University of Chiapas, Mexico, entitled ***"University Environmental Sustainability: Strategies and Perceptions at UNACH - A Case Study".*** This study aims to identify and analyse the strategies and actions that support environmental education and the university community's perception of the environmental culture promoted at the School of Administrative Sciences Campus Arriaga of the Autonomous University of Chiapas.

The research approach is descriptive, based on a case study that draws on three main sources of information: institutional documents, research or consultancy projects, and interviews with members of the university community. Through 37 interviews with teachers, managers, administrators and students, perceptions of environmental issues were explored.

The results show the presence of eight environmental competence units in the accounting and management programmes. In addition, 23 long-term actions have been implemented between 2011 and 2023, as well as five research projects and four academic products related to the environment.

These results confirm that participants perceive that both educational programmes are committed to strengthening the environmental culture. In conclusion, the research shows that the substantive functions and intra-university actions have a positive impact on the adoption of environmental culture within the university community, and that the school focuses on comprehensive education with a high sense of responsibility and environmental awareness.

From Spain, our next contribution marks the opening of the Biological and Agricultural Sciences session with an original research paper entitled ***"Indicators for Agroecological Transition: Food security, nutrition, well-being and promotion of a sustainable food model".*** This study highlights the

trascender las definiciones teóricas y desarrollar principios prácticos y cuantificables en el campo de la Agroecología.

Los indicadores se erigen como herramientas esenciales que permiten cuantificar variables y comparar diferentes modelos. La propuesta de este estudio se enfoca en establecer indicadores cuantificables que evalúen directamente aspectos relacionados con la calidad alimentaria y nutricional. Esto responde a la demanda de una evaluación integral de los sistemas agroecológicos y busca mejorar las herramientas existentes para calcular indicadores.

Los parámetros propuestos abarcan aspectos de relevancia en la dieta diaria, como la variedad de alimentos en el plato, su contribución a la seguridad alimentaria, su composición nutricional y componentes bioactivos, características organolépticas, nivel de procesamiento y transformación de los alimentos consumidos, así como factores ambientales que influyen en el modelo de producción y su impacto en el bienestar humano. En resumen, este estudio es un paso crucial hacia la construcción de un marco cuantificable para la evaluación de la transición agroecológica y sus efectos en la alimentación, la nutrición y el bienestar.

Un egresado de la UCEVA, con estudios de maestría y asesor de la Alcaldía local de Kennedy, Bogotá DC, Colombia en urbanismo táctico, nos presenta un esclarecedor artículo de reflexión titulado "Desentrañando las Complejidades de los Virus Mosaico en la Agricultura Moderna". Este artículo ofrece una visión integral de la caracterización, impacto, diagnóstico, tratamiento y manejo de estos virus en el ámbito agrícola. El texto aborda la diversidad de los virus mosaico y su amplio rango de posibles huéspedes, lo que plantea desafíos significativos en su control. La falta de tratamientos eficaces y los desafíos prácticos del diagnóstico requieren una vigilancia constante y un seguimiento epidemiológico para prevenir su propagación. El artículo comienza con una caracterización general de los virus mosaico, un grupo heterogéneo de virus que abarca numerosos taxones. Luego se exploran los síntomas distintivos de las infecciones por virus mosaico (que deben su nombre a su apariencia en mosaico), los métodos de diagnóstico, el rango de huéspedes, los modos de transmisión y las posibles estrategias de tratamiento.

need to move beyond theoretical definitions and develop practical and quantifiable principles in the field of agroecology.

Indicators are essential tools for quantifying variables and comparing different models. The proposal of this study focuses on establishing quantifiable indicators that directly assess aspects related to food and nutritional quality. It responds to the demand for a comprehensive assessment of agroecological systems and seeks to improve existing tools for calculating indicators. The proposed parameters cover aspects relevant to the daily diet, such as the variety of foods on the plate, their contribution to food security, their nutritional composition and bioactive components, organoleptic characteristics, the degree of processing and transformation of the food consumed, as well as environmental factors that influence the production model and its impact on human well-being. In summary, this study is a crucial step towards establishing a quantifiable framework for assessing the agro-ecological transition and its impact on food, nutrition and well-being.

A UCEVA graduate, Master's Degree holder and Tactical Urban Planning Advisor to the Mayor's Office of Kennedy, Bogotá DC, Colombia, presents an enlightening and thought-provoking article entitled ***"Unravelling the Complexities of Mosaic Viruses in Modern Agriculture".*** The article provides a comprehensive overview of the characterisation, impact, diagnosis, treatment and management of these viruses in agriculture. It highlights the diversity of mosaic viruses and their wide range of potential hosts, which pose significant challenges to their control. The lack of effective treatments and the practical challenges of diagnosis require constant surveillance and epidemiological monitoring to prevent their spread.

The article begins with a general characterisation of mosaic viruses, a heterogeneous group of viruses comprising numerous taxa. It then examines the characteristic symptoms of mosaic virus infections (named after their mosaic appearance), diagnostic methods, host range, modes of transmission and possible treatment strategies.

La tercera edición culmina con una destacada contribución del Dr. Miguel Ángel Altieri, una autoridad mundial en Agroecología, quien, junto a Clara Inés Nicholls, presenta el estudio titulado: "***Agroecología, Policrisis Global y Transformación de Sistemas Alimentarios***". En este cierre magistral, el Dr. Altieri resalta el papel estratégico de la agroecología en la conducción del mundo hacia una transición agrícola resiliente, biodiversa y productiva, capaz de proporcionar alimentos saludables y accesibles a nivel local y regional, a pesar de las diversas crisis que azotan al planeta. Incluso antes del conflicto en Ucrania, la economía mundial ya se veía afectada por múltiples crisis, que incluían la crisis climática, la pandemia de COVID-19 y el aumento de los costos de insumos y alimentos.

Es innegable que el sistema alimentario mundial actual requiere una profunda reforma. Está marcado por la desigualdad, el hambre, la degradación ambiental, la crisis climática y los abusos contra los derechos humanos y laborales. La agroecología emerge como una alternativa viable, que incluye una auténtica reforma agraria para garantizar que los derechos sobre la tierra, el agua, las semillas y la agrobiodiversidad estén en manos de los campesinos que producen alimentos, en lugar del sector empresarial. La agroecología, como una alternativa real al sistema alimentario industrial, proporciona principios y prácticas para respaldar a los pequeños agricultores en la producción de alimentos para sus comunidades y para alimentar al mundo de manera sostenible y saludable. Este artículo subraya la importancia de esta transición hacia sistemas alimentarios más justos y sostenibles.

Esperamos sinceramente que esta tercera edición de la revista Magna Scientia UCEVA haya sido de su completo agrado. Hoy, celebramos con alegría junto a nuestros estimados investigadores y lectores de todo el mundo. Nos complace compartirles la emocionante noticia de que hemos logrado la inclusión de nuestra revista en Latindex y en DOAJ. Este logro es el resultado del esfuerzo incansable de nuestro equipo editorial y del apoyo inquebrantable de todos ustedes, nuestros valiosos lectores. Su compromiso y contribuciones son fundamentales para que Magna Scientia UCEVA continúe creciendo y contribuyendo al desarrollo de una UCEVA más grande.

The third edition culminates with an outstanding contribution from Dr Miguel Ángel Altieri, a world authority on agroecology, who, together with Clara Inés Nicholls, presents the study ***"Agroecology, Global Polycrisis and Food Systems Transformation".*** In this keynote address, Dr Altieri highlights the strategic role of agroecology in guiding the world towards a resilient, biodiverse and productive agricultural transition, capable of providing healthy and accessible food at local and regional levels, despite the various crises plaguing the planet.

Even before the conflict in Ukraine, the global economy was being hit by multiple crises, including the climate crisis, the COVID-19 pandemic and rising input and food costs. These challenges have had a devastating impact, particularly on the poorest populations in low-income countries. The war in Ukraine, a major global food producer, has exacerbated these problems.

There is no denying that the current global food system is in need of profound reform. It is characterised by inequality, hunger, environmental degradation, climate crisis and human and labour rights violations. Agroecology is emerging as a viable alternative, including genuine agrarian reform to ensure that rights to land, water, seeds and agrobiodiversity are in the hands of the farmers who produce food, rather than the corporate sector.
As a real alternative to the industrial food system, agroecology offers principles and practices to support small-scale farmers to produce food for their communities and feed the world in a sustainable and healthy way. This article highlights the importance of this transition to more just and sustainable food systems.

We sincerely hope that this third issue of Magna Scientia UCEVA has been to your complete satisfaction. Today we are joyfully celebrating with our esteemed researchers and readers from all over the world. We are pleased to share with you the exciting news that we have achieved the inclusion of our journal in Latindex and DOAJ. This achievement is the result of the tireless efforts of our editorial team and the unwavering support of all of you, our valued readers. Your dedication and contributions are fundamental in ensuring that Magna Scientia UCEVA continues to grow and contribute to the development of a greater UCEVA.

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Original Research Article | *Medicine*

Assessment of medical certification of cause of death at a tertiary care center in rural region of western Maharashtra, India

Evaluación de la certificación médica de la causa de muerte en un centro de atención terciaria de una región rural en Maharashtra occidental, India

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Abstract

The aim of this study was to evaluate the precision and compliance with international guidelines in the medical certification of cause of death at a rural tertiary care center in Western Maharashtra, India. Additionally, we aimed to identify prevalent errors and discrepancies while investigating the factors that influence the medical certification process at the center. By conducting this research, we sought to obtain comprehensive insights into the accuracy of cause of death documentation and contribute to enhancing the adherence to standardized practices in this crucial aspect of medical practice. The Medical Certificate of Cause of Death (hereafter MCCD) is an important document issued by a doctor for which the World Health Organisation has prescribed a standard format, together with the International Classification of Diseases (hereafter ICD). In it, the doctor records the time, causes and circumstances of the deceased person's death. 615 MCCD forms were available during two years from the MAEER MIT Pune's MIMER Medical College & BSTR Hospital, Talegaon Dabhade and Pune. All of them were scrutinized for the completeness of the certificate and tried to find out the cause of death in which underlying cause of death was written. Data was analyzed and expressed in the percentage form. Ethical clearance was obtained from the Institutional ethics committee (No. IEC/MIMER/2021/761). Main leading cause of death in the present study was disease of circulatory system 868 (29.35%), followed by Neoplasm (16.54%) and Certain infectious and parasitic disease (16.44%). The present study showed incompletely and inaccurately filled MCCD forms. Therefore, adequate training and proper sensitization of the doctors regarding the usefulness of MCCD data is required.

Resumen

El objetivo de este estudio fue evaluar la precisión y el cumplimiento de las directrices internacionales en la certificación médica de la causa de muerte en un centro rural de atención terciaria de Maharashtra occidental, India. Además, nos propusimos identificar los errores y discrepancias prevalentes e investigar los factores que influyen en el proceso de certificación médica en el centro. Con esta investigación pretendíamos obtener información exhaustiva sobre la exactitud de la documentación de la causa de muerte y contribuir a mejorar el cumplimiento de las prácticas normalizadas en este aspecto crucial de la práctica médica. El Certificado Médico de Causa de Muerte (en adelante MCCD) es un importante documento emitido por un médico para el que la Organización Mundial de la Salud ha prescrito un formato estándar, junto con la Clasificación Internacional de Enfermedades (en adelante CIE). En él, el médico anota la hora, las causas y las circunstancias de la muerte de la persona fallecida. Durante dos años se dispuso de 615 formularios MCCD del Colegio Médico MIMER y el Hospital BSTR del MAEER MIT de Pune, Talegaon Dabhade y Pune. En todos ellos se examinó si el certificado estaba completo y se intentó averiguar la causa de muerte en la que estaba escrita la causa subyacente. Los datos se analizaron y expresaron en forma de porcentaje. Se obtuvo la autorización ética del comité de ética institucional (No. IEC/MIMER/2021/761). La principal causa de muerte en el presente estudio fueron las enfermedades del sistema circulatorio 868 (29.35%), seguidas de las neoplasias (16.54%) y ciertas enfermedades infecciosas y parasitarias (16.44%). El presente estudio puso de manifiesto que los formularios MCCD se rellenaban de forma incompleta e inexacta. Por lo tanto, se requiere una formación adecuada y una correcta sensibilización de los médicos respecto a la utilidad de los datos del MCCD.

Introduction

Mortality statistics are essential for the welfare of the community, for health planning, for the management of health programmes, and for building scientific databases for medical research. It is mandatory for every doctor to issue a cause of death certificate when a patient dies. The Medical Certification of Cause of Death (MCCD) is the document in which the doctor records the time, causes and circumstances of the death of an individual. In India, it is carried out under the Government Medical Certification Scheme under the Registration of Births and Deaths Act, 1969. [1]. The MCCD consists of two parts: the first part deals with the immediate cause (i.e. the final injury or illness that caused the death) and the underlying or antecedent cause (i.e. the illnesses, injuries or other circumstances that set-in motion the series of events leading to the immediate cause). The second part deals with the contributing cause (which is defined as any significant condition that contributes to the death but does not directly cause it) [2].

The MCCD supports the judicial system in civil cases such as insurance claims, compensation claims, etc. Causes of death are classified according to the International Statistical Classification of Diseases (ICD). It is required for uniform coding of deaths. ICD-10 is currently used for MCCD [3]. Inaccuracies and incomplete MCCD will lead to biased estimation of several epidemiological parameters. A complete and reliable MCCD is a prerequisite for a good registration system.

The aim of this study was to evaluate the precision and compliance with international guidelines in the medical certification of cause of death at a rural tertiary care center in Western Maharashtra, India. Additionally, we aimed to identify prevalent errors and discrepancies while investigating the factors that influence the medical certification process at the center. By conducting this research, we sought to obtain comprehensive insights into the accuracy of cause of death documentation and contribute to enhancing the adherence to standardized practices in this crucial aspect of medical practice.

Methods

The descriptive observational study was conducted in a MIMER Medical College, BST Rural Hospital area of Talegaon Dabhade, Pune. MCCD forms of all deaths are routinely completed by the doctors and these forms are then sent to the medical records department. Cause of death certificates issued by the attending physician along with history and treatment records were studied and analysed to assess the accuracy and completeness in filling up the forms as per the prescribed guidelines [4-8]. The majority (63%) were issued by the medical department. In 75 out of 615 (12.2%) forms, age was either not mentioned or was corrected. Twenty-nine (29.6%) certificates had more than two errors, the most common being no time interval and sometimes multiple causes of death. Only seven (7.1%) of the 98 certificates examined had no errors.

Results

The audited medical certificates of cause of death issued between September 2021 to March 2022. Out of total 615 MCCD forms, 614 (99.83%) mentioned age and 609 (99.02%) mentioned sex of the deceased person**.** Only 526 (85.52%) forms were completely filled. The completeness for immediate cause, antecedent cause and underlying cause was 95.56%, 66.67% and 40% respectively. Main leading cause of death in the present study was disease of circulatory system 178 (28.94%), followed by Neoplasm (16.54%) and certain infectious and parasitic disease (16.44%) [9]. These results confirm the concepts of errors observed in the MCCD forms, as shown in Table 1.

Table 1. Errors observed in MCCD forms

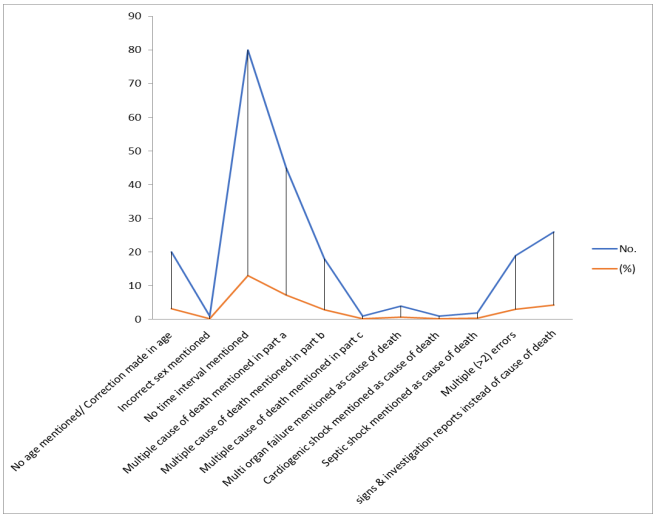
Error observed in MCCD	No. (%)
i. No age mentioned/ Correction made in age	20 (03.2)
ii. Incorrect sex mentioned	01 (0.16)
iii. No time interval mentioned	80 (13.0)
iv. Multiple cause of death mentioned in part i	45 (07.3)
v. Multiple cause of death mentioned in part ii	18 (02.9)
vi. Multiple cause of death mentioned in part iii	01 (0.16)
vii. Multi organ failure mentioned as cause of death	04 (0.65)
viii. Cardiogenic shock mentioned as cause of death	01 (0.16)
ix. Septic shock mentioned as cause of death	02 (0.32)
x. Multiple (>2) errors	19 (03.0)
xi. signs and investigation reports instead of cause of death	26 (04.2)

Furthermore, the evaluation of the Medical Certification of Cause of Death (MCCD) at the rural tertiary care center in Western Maharashtra, as depicted in figure 1, yielded valuable visualizations of the observed errors. This assessment also shed light on specific types of errors encountered during the

process.

- Notably, in 20 cases (3.2%), the age of the deceased was either omitted or required corrections. It is essential to accurately record the age as it plays a vital role in determining the cause of death and facilitating demographic analysis.

Figure 1. Errors observed in MCCD forms



- Incorrect sex mentioned: In one case (0.16%), the sex of the deceased was incorrectly documented. This error can lead to inaccurate data analysis and interpretation.

- No time interval mentioned: In 80 cases (13.0%), the time interval between the onset of illness and death was not specified. This information is vital for understanding the progression and severity of the condition leading to death.

- Multiple causes of death recorded in part *i*. In 45 cases (7.3%), multiple causes of death were recorded in part *i* of the MCCD. This can complicate the interpretation of the primary cause of death and affect accurate statistical analysis.

- Multiple causes of death recorded in part *ii*. Similarly, in 18 cases (2.9%) multiple causes of death were recorded in part *ii* of the MCCD. This can lead to confusion in determining the underlying cause of death.

- More than one cause of death was mentioned in part *iii*. In one case (0.16%) multiple causes of death were recorded in part *iii* of the MCCD. Again, this may make it difficult to identify the primary cause of death.

- Multiple organ failure listed as cause of death In four cases (0.65%), multi-organ failure was recorded as the cause of death. Although multi-organ failure may be a consequence of an underlying disease, it is not considered a specific cause of death and should be further specified.

- Cardiogenic shock listed as cause of death: In one case (0.16%), the cause of death was attributed to cardiogenic shock. Similar to multi-organ failure, cardiogenic shock is a clinical condition resulting from an underlying disease and should not be considered as the primary cause of death.

- Septic shock listed as cause of death In two cases (0.32%), septic shock was recorded as the cause of death. Similar to the previous points, septic shock is a manifestation of an underlying infection and should be related to the specific infection causing it.

- Multiple (>2) errors: In 19 cases (3.0%), more than two errors were found in the MCCD. The overall accuracy and reliability of cause of death certification is reduced by these multiple errors.

- Signs and findings rather than causes: In 26 cases (4.2%), the MCCD included signs and examination reports instead of explicitly stating the cause of death. This lack of specificity can hinder data analysis and understanding of the primary cause of death.

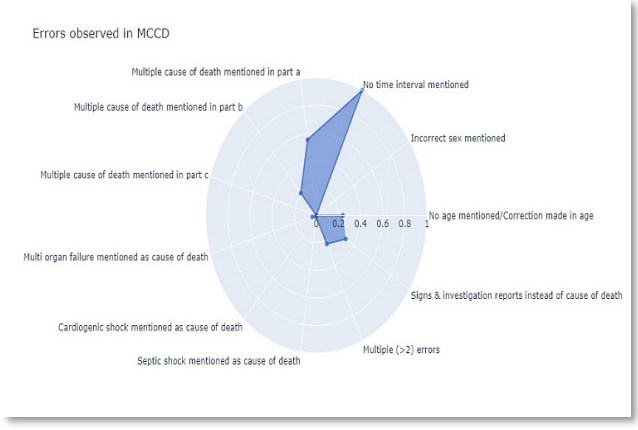
The data collected from the assessment is described by means of a bar chart, which illustrates the frequency of the different types of errors observed in the MCCD [10]. The x-axis of the graph represents the different categories of error, such as missing or corrected age, incorrect documentation of sex, missing time intervals, multiple causes of death mentioned in different parts of the certificate, mention of non-specific conditions such as multi-organ failure, cardiogenic shock and septic shock as causes of death, multiple errors within a single certificate, and documentation of signs and examination reports instead of the cause of death [11].

The y-axis represents the frequency or percentage of cases associated with each error category. Each defect category is represented on the graph as a bar, with the

height of the bar corresponding to the number or percentage of cases for that particular defect. Data labels are provided at the top of each bar, showing the specific numerical values [12]. This visual representation of the data in the form of a bar chart enhances the understanding and comparison of the prevalence of different errors in the MCCD. The research article highlights the importance of improving accuracy, compliance and standardisation in the medical certification process based on the findings and insights derived from the bar chart (see figure 2).

The Radargraph (figure 2) is a powerful visual tool which provides a complete picture of the errors detected by the MCCD. Each axis represents a specific failure type and data points along those axes indicate failure size. By comparing the positions of the data points, it is possible to quickly identify the types of errors that are more and less frequent. The filled area within the graph illustrates the overall distribution of defects across defect types. Hovering over the data points reveals tooltips showing the defect type and count values, allowing more detailed examination. The radial axis, ranging from 0 to 1, facilitates a relative understanding of the significance of the errors. With a clear title and no legend, the radar plot provides a concise yet informative visual assessment of the error distribution and severity within the MCCD dataset.

Figure 2. The visualisation of the radar chart observed in MCCD



Discussion

The correct completion and accuracy of death certificates is essential for the collection of mortality statistics. To meet this need, doctors around the world are trained to complete death certificates. However, despite repeated instructions, trainings / workshops to the clinicians, errors are committed in writing the correct underlying cause of death. It is used as an indicator and as a tool for monitoring public health policies. It provides useful information on the geographical distribution of deaths. In order to obtain correct mortality statistics, it is necessary to raise awareness among doctors about the correct completion of MCCD forms.

The guidelines for completing the MCCD are not only on the back of every certificate, but there are also various handbooks available for easy reference. Nevertheless, inaccuracies in death certificates are a common problem. Data on these inaccuracies in completed MCCD forms from academic institutions in India is scarce. These inaccuracies are due to the fact that medical students and doctors are not sufficiently taught the importance of writing down an authentic 'cause of death'. Instead of writing a legitimate basic cause of death, most of the practitioners attribute the cause of death to the mechanism of death, e.g. cardio-pulmonary arrest, as they are not informed about the appropriate 'cause of death'.

This happens because little attention is paid to the deceased's medical history. The filing of the MCCD is seen as a routine formality. Other factors contributing to errors include fatigue and lack of time. The Medical Certificate of Cause of Death is included in the curriculum for undergraduates, but they do not receive practical training in filing it until they are residents. Errors in death certification are a global problem, and reported rates of major errors in other institutions range from 34% to 37% [4-7].

Our study found that 85.52% of respondents had satisfactory knowledge, whereas Undavalli et al. [8] observed that 36% of the members had more than 50% of the knowledge score, which is considered as satisfactory knowledge. Analysis of the MCCD of each deceased patient during ward rounds and during the annual course of death certification will help to improve the accuracy of death certification. In the present study, it was difficult to compare inaccuracies with other studies because of the different benchmark used to construct errors. Despite the magnitude of the problem, there are few studies on educational interventions to improve the accuracy of MCCD completion in India.

The following recommendations, if implemented, will

go a long way in addressing the factors that adversely affect the accurate completion of medical certificates of cause of death. Firstly, it is strongly recommended that mandatory, frequent programmes on death certification be conducted for all residents and medical officers. The error rate will be reduced if these programmes are repeated regularly in institutions. Then the importance of completing the MCCD can be emphasised. As an educational resource for residents and attending physicians, an instructional resource should be made available to them. Other suggestions for improvement include regular audit of all MCCD by an independent body and regular updates in the form of CME programmes and death review meetings.

Conclusion

The MCCD scheme plays a crucial role in regulating and ensuring consistency in the issuance of cause of death certificates by medical practitioners. In order to minimize errors, it is imperative to raise awareness among doctors about the value of MCCD data through effective sensitization initiatives and provide them with adequate and periodic refresher training. Additionally, the supervision of all death certificates may be necessary when deemed appropriate.

The present study reveals a significant correlation between the knowledge score and various factors such as the current department of posting, current designation, gender, religion, and work experience. A well-executed MCCD system is essential for maintaining accurate records within an institution. Consequently, the findings of this study strongly suggest the implementation of workshops, seminars, and induction training programs specifically designed for interns and junior doctors. Furthermore, regular audits should be conducted to minimize further errors in the completion of MCCDs.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of views and not that of the institution to which they belong.

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Systematic Review Article | *Medicine*

Role of genetics and lifestyle in dysmenorrhea

El rol de la genética y estilo de vida en dismenorrea

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Palabras clave:

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Abstract

The aim of this systematic review was to identify the current state of knowledge on the association between susceptibility genes associated with this disorder and the lifestyle of patients (including diet, habits and stress levels). It also highlighted the advances made in this field of study, from a constructive point of view, and pointed out the perspectives for research into this disorder. Dysmenorrhoea, as a primary and secondary disorder, is one of the main causes of partial or total disability in the life cycle of women, both in reproductive age and later. It is recognised as a painful and disabling disorder which, depending on the cultural context, may or may not be cured by medical care, physiotherapy and the use of pain-relieving drugs, from an unknown aetiology (primary dysmenorrhoea) or concomitantly to surgical intervention (secondary dysmenorrhoea). Lifestyle, habits and diet have been identified as related to the intensity of pain and the disability it causes (active or passive use of cigarettes, consumption of alcohol, etc.), and genes related to the interpretation of pain generated by the patient from the morphology of the hypothalamus and the associative function of pain (BNDF Val66Met polymorphism) have been identified, as well as alterations in cytokines (in primary dysmenorrhoea), prostaglandins and an influence of the Cyp1A1 gene (in passive smokers). The study perspective is usually non-integrative and limited to the site studied, as well as to professional, laboratory, imaging (gynaecological and genetic) and/or molecular resources, which can only in a few cases be of an integral approach. Limitations are compounded by the fact that not all the populations studied are usually educated about menstruation, which also limits compatibility and comparability among studies.

Resumen

El objetivo de esta revisión sistemática fue identificar el estado actual de los conocimientos sobre la asociación entre los genes de susceptibilidad asociados a este trastorno y el estilo de vida de los pacientes (incluyendo dieta, hábitos y niveles de estrés). También se destacaron los avances realizados en este campo de estudio, desde un punto de vista constructivo y se señalaron las perspectivas para la investigación de este trastorno. La dismenorrea como trastorno primario y secundario, es una de las principales causas de incapacidad parcial o total en el ciclo vital de la mujer, tanto en edad reproductiva como posteriormente. Se reconoce como un trastorno doloroso e incapacitante que, dependiendo del contexto cultural, puede curarse o no con atención médica, fisioterapia y el uso de fármacos analgésicos, de etiología desconocida (dismenorrea primaria) o concomitante a una intervención quirúrgica (dismenorrea secundaria). Se ha identificado que el estilo de vida, los hábitos y la dieta están relacionados con la intensidad del dolor y la discapacidad que provoca (uso activo o pasivo de cigarrillos, consumo de alcohol, etc.), y se han identificado genes relacionados con la interpretación del dolor generado por el paciente a partir de la morfología del hipotálamo y la función asociativa del dolor (polimorfismo BNDF Val66Met), así como alteraciones en citoquinas (en dismenorrea primaria), prostaglandinas y una influencia del gen Cyp1A1 (en fumadores pasivos). La perspectiva del estudio suele ser no integradora y limitada al lugar estudiado, así como a los recursos profesionales, de laboratorio, de imagen (ginecológicos y genéticos) y/o moleculares, que sólo en unos pocos casos pueden tener un enfoque integral. A las limitaciones se suma el hecho de que no todas las poblaciones estudiadas suelen estar educadas sobre la menstruación, lo que también limita la compatibilidad y comparabilidad entre estudios.

Introduction

Menstruation is a normal physiological process, which occurs approximately every month in women and can generate some level of discomfort and pain, without being disabling or affecting their daily activities [1]. In contrast, painful dysmenorrhea, or painful menstruation, is a common reason for gynecological consultation among adolescents and women, affecting about 90% of reproductive age [2 - 4].

Despite its high prevalence rate and effect on daily life, 76.1% of women still believe that dysmenorrhea is a natural part of the menstrual cycle and only 14.8%, consider medical treatment necessary [5]. In definition, dysmenorrhea as a debilitating syndrome [6], is known as the presence of painful cramping of uterine origin occurring during menstruation and represents one of the most common causes of pelvic pain and menstrual disorder [7]. It usually occurs during the first 1 to 3 years after menarche and is accompanied by sweating, lack of appetite, headache, distractibility, nausea, vomiting, and dizziness [8].

It is not a recognized gynecological disorder [9] and is associated with decreased self-rated general health [10], in combination with depressive [11, 12] and anxious symptoms [13,14]. Dysmenorrhea as a condition of public health concern that can be classified into two distinct types: primary and secondary. Primary dysmenorrhea (PDM) [15] is defined as painful menses in women with normal pelvic anatomy, usually beginning during adolescence [16-18]. It is attributed to excessive pathological uterine contractions, without any other changes in the lesser pelvic area [19] and is recognized as being caused by increased or unbalanced endometrial prostanoid production during menstruation [20]. Secondary dysmenorrhea, is recognized as menstrual pain associated with an underlying pathology [21, 22], and is associated with a prevalence of acquired changes, as well as anatomical and functional abnormalities of the generative organs [6, 23].

Onset can be years after menarche [18], but can also occur as a new symptom in a woman in her 40s or 50s after the onset of an underlying condition [18,24]. It can be caused by a dozen conditions including endometriosis, pelvic inflammatory disease, intrauterine devices, irregular cycles, infertility, ovarian cysts, adenomyosis, fibroids, polyps, intrauterine adhesions or cervical stenosis [25].

The burden of dysmenorrhea is greater than any other gynecologic ailment [26], being the leading cause of morbidity in women of reproductive age, regardless of age, nationality, and economic status [27-31]. The effects extend beyond individuals resulting annually in a significant loss of productivity in society [32,33]. According to the World Health Organization (WHO) , it is the most important cause of chronic pelvic pain [21], affecting between 1.7% and 97% of women [21]. In the U.S., it is responsible for the loss of 600 million work hours and two million dollars each year [28]. It appears to be associated, to a lesser extent with late menarche [12, 34-36] and to a greater extent with early menarche [12, 27, 37-39], as well as with menstrual cycle irregularity [12,40], prolonged [38] and heavier than normal menstrual flow [41], low weight and body mass index [42], inadequate physical exercise [21, 43], genetic predisposition [44], active and passive smoking [41,45-50], alcohol consumption [49, 50], low socioeconomic status, dietary habits [35, 51,52], stress and mental illness [42, 48]. According to authors such as Barcikowska et al. [53], although there are various reports about the factors that may predispose to its occurrence, the results are often contradictory [41,54, 55].

With regard to the underlying causes of dysmenorrhoea, various studies point to a complexity of biochemical reactions between the endocrine, vascular and immune systems, as well as the role of prostaglandins in its pathological mechanism [56]; they increase tone, uterine contractions and cause pain [20]. The excessive release of prostaglandins also explains the coexistence of other symptoms such as nausea and headache [57-59], and in particular their hyperproduction (at the uterine level) is associated with the prostaglandins PGF2 and PGF2a [60]. Unfortunately, cytokines and other pro-inflammatory factors (in PDM) have been less studied [31].

From the structural perspective of the central nervous system, recurrent menstrual pain is associated with central sensitisation, which in turn is associated with structural and functional changes [19,60]. In recent years, studies have developed with brain-derived neurotrophic factor (BDNF), associated with stress regulation [61], with higher expression in the hippocampus [15,62]. According to Duman & Monteggia [63], stress decreases BDNF expression through gamma-aminobutyric acid (GABA)-inhibitory interneurons in limbic structures particularly in the hippocampus as well as that anxiety levels in subjects with the Met/Met

polymorphism (MMP) exceed those of subjects carrying the Val polymorphism (MMP) [14].

Lee et al. [14] reported that genetic factors, such as this polymorphism [64] and OPRM1 A118G55, may influence the genotype-specific process, functional connectivity dynamics of the DPMS (descending pain modulatory system) in female with PDM, and Hirata et al. [65] reported that several genome-wide association studies (GWAS) have successfully identified genomic loci associated with age at menarche [66,67], menopause, dysmenorrhoea [15,68], endometriosis [69-72] and breast size [65,73].

The aim of this systematic review is to characterise a possible association between susceptibility genes in this painful disorder and lifestyle, including diet, general habits and stress levels, and to establish their direct incidence in this condition. It will also identify methodological breakthroughs and/or conceptual gaps in order to clarify the current state of knowledge about the causes and factors involved in dysmenorrhoea, as well as the limitations of the studies developed so far and the perspectives of this field of research.

Methods

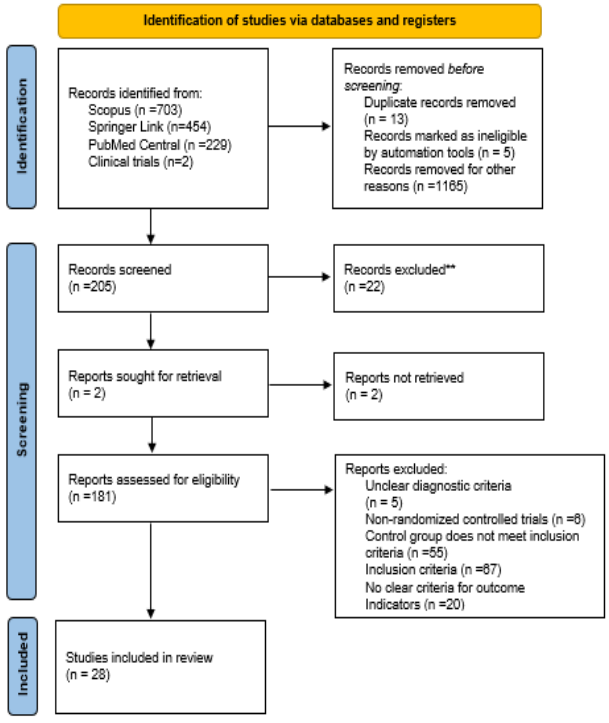
This review was conducted following the recommendations of Cochrane et al. [74] and PRISMA [75]. The NCBI and Science Direct databases were searched between the months of January and October 2022 using the search terms "Dysmenorrhoea" AND "Genes"; "Dysmenorrhoea" AND "lifestyle" in different combinations in Spanish and English. Effective information was obtained from the year 2007 to 2022, with a total of 28 articles selected for the headings lifestyle and multidisciplinary studies with occupational, molecular and imaging (including RMN) components (see figure 1).

Results

Role of lifestyle in dysmenorrhea

Dysmenorrhoea as a painful disorder has been studied from the realities of the environments of interest to the researchers (isolated populations with little education or populations of university and/or health workers with academic training in their condition) and taking into account the demographic characteristics of the population, including the influence of their phenotype in harmful habits or that have been considered, in the literature, as influencing the onset, incidence or worsening of symptoms. In many cases, the studies are limited to the analysis of vocative questionnaires of the self-assessment survey type, as well as a few studies that can combine the gynaecological assessment by imaging and physical examinations, biochemical, molecular studies and, in specific cases, genetic imaging, analysis of the central nervous system.

Figure 1. Flowchart of study selection for systematic review



From this literature review and meta-analysis, it emerged that the studies associating lifestyle and the severity of dysmenorrhoea were usually limited in scope to various factors, including the patient's knowledge of menstruation, the cultural education of the population studied, the bleeding, pain and functional limitations caused by menstruation, as well as the environment and resources in which it can develop. In order to present the information analysed in a systematic way and thus facilitate its interpretation, the information collected has been classified under two subheadings. The first describes the methodology used in the different types of studies reviewed (from the allocation of the sample analysed

to the design of the questionnaires and their subsequent statistical analysis), and a second reports on the factors associated with lifestyle and their incidence on the severity of dysmenorrhoea, mostly associated with primary dysmenorrhoea, the stage chosen by most researchers, depending on the exclusion factors applied to the selected population.

Experimental methodology

The research methodology on this subject has tended to evolve towards the use of mixed questionnaires that include questions on the patient's lifestyle before, during and after the menstrual period, as well as their design with heterogeneous objectives, including causality and risk factors in dysmenorrhoea. They evaluate: the prevalence of dysmenorrhoea and the study of its impact on the quality of life of patients [17]; the relationship between lifestyle and primary dysmenorrhoea [20]; the determination of its frequency according to different definitions in female, in order to identify its associated factors [42]. Similarly, we seek to determine its prevalence and associated factors in particular age groups (Ethiopia - high school students, Muluneh et al. [76]; Spain- university students [1], describe their menstrual characteristics, lifestyle habits, as well as evaluate the impact of specific professions on the risk of the condition, as is the case of health care workers (nurses) considered to be at high risk, based on demographic information, attitudes about menstruation and their influencing factors [12].

These studies are generally mostly prevalent in Taiwan [12], Japan [65], Iran [20], Turkey [25], Italy [42], Spain [1], Poland [56] and Ethiopia [76]. They are usually conducted in one-month point sampling efforts [12, 17, 20, 42] and very few studies evaluate and compare cohorts in different years, or follow them up (e.g. in genetic imaging studies) [14]. The sample size is usually calculated based on the size of the population addressed and the power of the statistical test to be performed [12], or from the total population found in the randomly evaluated institution, course or subsection [76].

In terms of effective sample size (n), groups smaller than 70 individuals (59 with primary dysmenorrhea and 68 as control, [14]) or larger than 200 (250 individuals, [20]; 258 individuals [1]; 408 individuals [42]; 420 individuals; nurses [12], 539 individuals [76]; 623 individuals [17], with prevalence by larger sample sizes. Likewise, it has been differentiated among educational levels, including middle or high schools [17, 76], universities such as Dumlupinar University [17], Sari University of Medical Sciences [20], specific Institutes or faculties in Universities or hospitals (Department of Pediatrics, Gynecology and Obstetrics, University Polyclinic Hospital of Modena [42]; Faculty of Nursing of Ciudad Real, University of Castilla-La-Mancha [1], and medical or care staff (nurses) [12].

The cohorts analyzed are usually delimited to female as their target population (aged at least 18 years [12], aged 18-25 years [20]) and the studies are generally of pre-set order, based on self-assessed questionnaires with a variable number of questions as well as inclusion or not of subsections, where participants are informed that their completion is optional [25, 76], with variable duration between 10 to 40 minutes per session (10-15min [1]; 35-40 min [17]). Response sessions are generally single [17] or split, within the same questionnaire and conducted in the presence of the principal investigator [17] or with supervision of school staff (e.g., volunteer teachers [76]. Only in some cases, such as Muluneh et al. [76], theoretical sessions are conducted about the base concepts, which are to be worked with the participants, in order to give clarity to the questionnaire (e.g. concept of dysmenorrhea, physical activity, non-academic homework, sugar consumption); which are usually based on indices such as the HRQoL (from High Rate Quality of Life [17]) or are pre-established, by the same authors such as Muluneh et al. [76] and/or by referenced authors, such as Chiou et al. [12], Chiou & Wang [77], Mahmoodi et al. [78], Potur et al. [14], Aktaş [2], Habibi et al. [79] and Tomás-Rodríguez et al. [80]. Likewise, they are usually based on international standards, such as the SF-36 (The Short Form-36) or the IPAQ (International Physical Activity Questionnaire [20]).

Scales for the assessment of emotional states and physiological affect are usually instrumented from standard scales such as the scales: *i*) VAS (Visual Analogue Scale) [1,17,42], McGill (McGill pain index

or MPQ) [15,20] or NPRS (Numeric Pain Rating Scale [20]), to stratify menstrual pain (including analgesic effect and interference with social or academic activities [42]; *ii*) MSS (Multidimensional scoring system) [17], *iii*) DKS (Dysmenorrhoea Knowledge Scale) [12] and *iv*) MAS (Menstrual Attitude Scale) [12]. In some cases, patients who reported pain were subjected to additional questionnaires, seeking to establish the characteristics of the pain and its influence on their ability to perform their daily activities [1] and in others, the presence of chronic diseases such as diabetes, high blood pressure, underlying heart disease or infectious diseases, as well as not having self-reported symptoms such as vaginal burning, itching or abnormal discharge, and not having a history of gynecological surgeries were considered as exclusion factors for participants [20].

Some very specific studies that seek to assess the influence of dysmenorrhea pain on brain function and plasticity [14] are accompanied by imaging (MRI) to investigate global, regional, modular structure metrics of resting-state brain functional networks (in female with PDM) [14] and generally, they usually examine and diagnose patients using the same clinical gynecological management, as a control and baseline [14]. In these types of studies, exclusion criteria are more restrictive, such as: *i*) the use of oral contraceptives, hormonal supplements, Chinese herbal medicines, or any centrally acting medications (e.g., opioids, antiepileptics) in the 6 months prior to the study; *ii*) pathological disease of the pituitary gland; *iii*) organic pelvic disease; *iv*) any psychiatric or neurological disorder (e.g., premenstrual dysphoric disorder); *v*) any head injury with loss of consciousness or brain surgery; *vi*) immediate plans for pregnancy or a positive pregnancy test; *vii*) history of childbirth; and *viii*) having a metal implant/pacemaker, claustrophobia, or any contraindications regarding MRI [14]. Multidisciplinary assessment of psychological status throughout the menstrual cycle, including the Spielberger State Trait Anxiety Inventory, Beck Anxiety and Depressive Scales, and pain catastrophization scales during the menstrual (MENS) and postovulatory (POV) phases. The McGill pain questionnaire was also applied in order to assess their respective general and current (MENS and POV) experiences of menstrual pain and serum biochemical, gonadal serum hormone measurements were performed during the two phases examined, seeking to establish a correlation between all the factors examined [14].

Studies such as that of Hirata et al. [65], which evaluate traits related to primary and secondary sexual characteristics with a high impact on dysmenorrhea, during puberty and daily life in adulthood, address methodologies such as genome wide studies (GWAS, eQTL signals), related QTLs identified with phenotypic variables, significant associations for breast size, pain severity and menstrual fever [65]. In these cases, data is collected through specific databases or web pages (voluntary participation of users of the MTI women's health information website and applications) (http://www.mti.co.jp/eng/).

Population samples larger than 10000 individuals are usually included (11379) [14] and the study is conducted by constructing gynaecologically related phenotypes for the analysis of breast size and pain severity [65].

In general terms, statistical analysis of studies is usually performed in regression terms for categorical [20,42], linear [65], bivariate [76] and multivariate [12, 65]. Sociodemographic variables [17,41,76], such as personal, educational, physical, gynecological [1, 20,41], nutritional [17,20,42,76] and self-care factors [20], are included. In other cases, factors are divided into demographic [12], lifestyle and behavioral (including physical activity) [41,42,76], sugar consumption [17,42,76], coffee consumption [42,76], tea [76] and alcohol [42,76], cigarette use [42,76], chewing habits [76], salt consumption [17,42], fish intake [42], reproductive issues (age at menarche), [12] and menstrual patterns [1,76].

Muluneh et al. [76] argue that some experimental approaches, consider it necessary to assess the presence of a sentimental relationship or marital status [42], the use of oral contraceptives, gynecological pathologies and surgeries and associated risk factors [1,42]. From the ethical and regulatory point of view, these studies usually include informed consents [12,42], guaranteeing the anonymity of the participants [1,12,42] or confidentiality [76] and others even report, as an incidence, the obligatory nature presented at the time of their execution, contradicting precisely this premise [76].

Another valid approach to researching this disorder is presented in the literature, namely systematic reviews. In this group of research, Latthe & Champaneira [18] sought to establish the effects of pharmacological treatments on primary dysmenorrhea, including published studies of the Randomized Controlled Trial

(RCT) type and systematic reviews in English language, single-blinded, with 20 or more individuals (10 in each arm) and with a follow-up of more than 80%. Likewise, the authors valued including studies in women with primary dysmenorrhea or where a subgroup analysis was performed in women with primary dysmenorrhea [18]. Similarly, Petraglia et al. [31], conducted a systematic study in function of establishing how pain associated with dysmenorrhea is caused by prostaglandin hypersecretion and an increase in uterine contractility. These authors found that in primary dysmenorrhea, it is quite frequent in female and remains with good prognosis, although it is associated with low quality of life, in contrast to the secondary form of dysmenorrhea, where it is associated with endometriosis and adenomyosis, and where it may represent a key symptom of these conditions. Like the previous authors, it is noted that treatment alternatives include nonsteroidal anti-inflammatory drugs (NSAIDs), alone or combined with oral contraceptives or progestogens [31].

Habits, lifestyle and their influence on the disorder

In 2010, Unsal et al. [17] conducted a study to assess the prevalence of dysmenorrhoea and its impact on health-related quality of life (HRQoL) in a group of female undergraduate students at Dumlupinar University School of Health in western Turkey. Eight domains were assessed using a self-administered questionnaire. Physical functioning, social functioning, role limitations due to emotional problems (role-emotional), role limitations due to physical problems (role-physical), bodily pain, vitality, mental health and general health perception (Turkish version of the SF-36) were included. As a result, the prevalence of dysmenorrhoea was found to be 72.7% and was significantly higher in coffee drinkers, women with a long duration of menstrual bleeding (± 7 days) and those with a positive family history of dysmenorrhoea compared to the others (P<0.05). No statistically significant differences were found between the groups with and without dysmenorrhoea [17].

According to multivariate analysis, coffee consumption (OR 2.084), duration of menstrual bleeding ±7 days (OR 1.590) and positive family history of dysmenorrhea (OR 3.043), were significant risk factors for the disorder. For the domains assessed, except for social functioning, emotional role and mental health, the SF-36 points received in others were higher in women with dysmenorrhea (P <0.05), thus interpreted as configuring a common health problem that has negative effects on health-related quality of life (HRQoL) among female university students. Statistically, there were no differences between the habits and medical characteristics of female students with dysmenorrhea, with the exception of coffee consumption (P <0.001), the mean age at menarche was 13.38 ± 1.20, with a range of 10 to 18 and about 80% reported experiencing regular menstruation (79.8%) [17]. The mean menstrual cycle length of the female students in the study group was 28.73 ± 7.25 days (minimum 10, maximum 90) and the mean duration of menstrual bleeding was 5.73 ± 1.34 days, with a range between 3 and 10. Only 8.3% of the students reported using medications that regulate menstruation and approximately 50% of the students (47.4%) reported having a family history of dysmenorrhea, as well as no differences were revealed between menstrual characteristics and dysmenorrhea status, except for duration of menstrual bleeding and family history [17].

In contrast, Grandi et al. [42], conducted a study that aimed to determine the frequency of dysmenorrhea, identified by different definitions, in a population of female and to investigate factors associated with this complaint. 84.1% of the women reported menstrual pain, 43.1% reported that the pain occurred during all periods and 41% reported that it occurred during some periods. Women with menstrual pain had earlier menarche (P = 0.0002) and longer menstrual flow (P = 0.006), and the group was characterized by a higher prevalence of smokers (P = 0.031) and a lower prevalence of hormonal contraceptive users (P= 0.015). Pain intensity correlated (r= 0.302, P= 0.0001) positively with menstrual flow length (HR = 0.336), history of abortion (HR=3.640) and gynecologic pathologies (HR= 0.948), as well as negatively with age at menarche (HR=-0.225), hormonal contraceptive use (HR=-0.787) and history of gynecologic surgery (HR = -2.115) [42].

Considering the parameters of menstrual pain, need for medication and inability to function normally (absenteeism from the study or social activities) alone or together, the prevalence of dysmenorrhoea was 84.1% when considering menstrual pain alone, 55.2% when considering the association between menstrual pain and need for medication; 31.9% when considering the association between menstrual pain and absenteeism, and 25.3% when considering the association between menstrual pain, need for

medication and absenteeism (*P*=0.0001). Pain intensity by VAS (Visual Analog Scale), was independently (r =0.302, *P*=0.0001) and directly related to menstrual flow length (HR = 0.336), history of miscarriage (HR = 3, 640) and gynecologic pathologies (HR = 0.948) and inversely related to age at menarche (HR=-0.225), use of hormonal contraceptives (HR=-0.787) and history of gynecologic surgery (HR=-2.115). Stratification according to VAS score did not coincide with the figures representing the need for medication and absenteeism. In fact, only 58% of those with severe menstrual pain had a disorder that required concomitant treatment and affected quality of life to the point of inducing absenteeism [42]. Therefore, the authors consider the likelihood of having more severe dysmenorrhea to be directly related to, but not coincident with, pain intensity as measured by a visual analog scale, although at least one in four women experience distressing menstrual pain characterized by the need for medication and absenteeism from study or social activities [42].

In 2018, Muluneh et al. [76] conducted a study on the school-aged population in Ethiopia, given the scarcity of demographic information, and sought to determine the prevalence and associated factors of dysmenorrhoea among high school students. Methodologically, they relied on an institution-based cross-sectional survey of middle and high school students in the city of Debremarkos. As a result, the prevalence of dysmenorrhea was 69.3%, the adjusted odds ratio with respect to age was AOR (95% CI) = 1.38 (1.15,1.65), family history of dysmenorrhea, AOR (95% CI) = 9.79 (4.99, 19.20); physical activity, AOR (95% CI) = 0.39 (0.13, 0.82), sugar intake, AOR (95% CI) = 2. 94 (1.54, 5.61); early menarche, AOR (95% CI) = 4.10 (1.21, 13.09); late menarche, AOR (95% CI) = 0.50 (0.27, 0.91); heavy menstrual periods AOR (95% CI) = 2.91 (1. 59, 5.35) and sexual intercourse AOR (95%CI)=0.24 (0.10,0.55,), presented a statistically significant association with the occurrence of this disorder [76]. It was found that more than half (54.2%) of the students surveyed did not do any physical activity, although 70% of the students were involved in simple non-academic tasks at home and none of them had smoked.

Likewise, it was determined that the mean age at menarche was 13.16 ± 1.76 years with a range of 9-17 years and that 7.6% of the individuals had a history of sexual intercourse, of which 48.7%, had a history of contraceptive use. Only 1 (2.6%) had a history of pregnancy and 75% of the total respondents had regular menstrual cycles, with a normal duration (21-35 days), in 94.0% of the cases. Of the total 511 respondents, 354 (69.3%) had dysmenorrhea and for 168 (47.5%) and 144 (40.7%) the pain started 1-2 days before and just after the onset of menstruation respectively, as well as 76.8% of the total experienced dysmenorrhea during each menstrual period [76]. In conclusion, age, positive family history of dysmenorrhea, physical activity, excessive sugar intake, early menarche, late menarche, sexual intercourse and heavy menstrual periods had a statistically significant association with the occurrence of dysmenorrhea in the evaluated population [76].

In a cross-sectional study conducted by Fernández-Martínez et al. [1] in female from the nursing faculty of Ciudad Real at the University of Castilla - la Mancha, the aim was to determine the prevalence of primary dysmenorrhea and to describe their menstrual characteristics, lifestyle habits and associated risk factors; this included sociodemographic characteristics, lifestyle habits, personal and gynecologic history and pain severity, using the visual analog scale. As a result, the prevalence of dysmenorrhea was 74.8% (n = 193) with a mean pain intensity of 6.88 (±1.71); 38.3% of the students described their menstrual pain as severe and 58% as moderate. In addition to menstrual pain, the most frequently reported symptoms were edema (92.7%), irritability (81.9%) and fatigue (79.3%) [1]. Bivariate analysis showed statistically significant differences between students with and without dysmenorrhea: a higher proportion of women with dysmenorrhea had longer duration of menstrual flow (p = .003), longer duration of menstrual cycle (p= .046), when they were not using the oral contraceptive pill (p = .026) and had a family history of dysmenorrhea (p = .001) [1].

Binary logistic regression analysis (backward stepwise) showed that the risk factors: drinking cola soft drinks, duration of menstrual flow, eating meat and having a first-degree relative with dysmenorrhoea had an influence on the disorder [1]. About 80% of students with dysmenorrhoea had menstrual bleeding lasting more than five days, with a menstrual cycle frequency of more than 29 days (79.9%) [1]. In addition, of the sample with dysmenorrhoea, 75.6% of students reported that their daily activities were affected, and a total of 91.2% of students with dysmenorrhoea were taking analgesics, of whom 77.7% were self-medicating, mainly when they reported worsening symptoms [1]. In the group with dysmenorrhoea, 26% drank alcohol, compared to

32.31% in the group without dysmenorrhoea. Regarding smoking, only 15% of the group with dysmenorrhoea smoked, compared to 23.08% of the group without dysmenorrhoea. Among the factors that were statistically significant, there was a difference in the consumption of tea, cola, simple sugars, meat and fruit three times a day and cooking food with olive oil [1].

According to their findings, Fernández-Martínez et al. [1] indicate that dysmenorrhea affects a large part of the Spanish university population and is configured as a problem that affects the daily life of female students. Likewise, they point out that there are known non-modifiable risk factors in the literature that increase the likelihood of suffering from dysmenorrhoea, such as having a first-degree relative who suffers from the problem. However, in terms of lifestyle and eating habits, and based on their previous findings, they state that further studies are needed to provide or confirm recommendations on the most advisable diets or lifestyle habits to reduce the risk of suffering from dysmenorrhoea [1].

In 2016, Abadi et al. [20] conducted a study to examine the relationship between lifestyle and primary dysmenorrhea in students of Sari University of Medical Sciences to facilitate lifestyle interventions among female. From the scores obtained on the lifestyle questionnaire, significant differences were observed between the groups with and without dysmenorrhea in terms of eating behavior (p = 0.008), physical activity (p = 0.011), stress (p = 0.041), and social relationships (p = 0.000). No differences were observed in terms of self-care (p= 0.115) vs. smoking, and drinking vs. drug use (p = .355). According to logistic regression analysis, age (OR = 1.208, p = 0.014), physical activity (OR = 1.008, p = 0.040) and social relationship (OR = 0.952, p = 0.002), were different in the two groups, in terms of age (p = 0.001) and degree of schooling (p = 0.011), but not in terms of BMI (p = 0.296), age at menarche (P = 0.0374), duration of menstruation (P = 0.54), menstrual cycle (P = 0.54), diet (P = 0.233), socioeconomic status (P = 0.346), grouped as eating behavior, self-care and stress [20].

The results showed that for each unit increase in the social relationship score, the odds of experiencing dysmenorrhoea decreased by 0.05. In other words, according to the authors, people with better social relationships were less likely to have dysmenorrhoea. In addition, a one-unit increase in physical activity score reduced the odds of experiencing dysmenorrhoea by 0.01; therefore, more physically active women are less likely to experience dysmenorrhoea. Similarly, the odds of experiencing dysmenorrhoea were found to decrease by 0.18 with age; therefore, women are less likely to experience this condition as they get older [20]. This research showed that a good lifestyle can reduce the severity of dysmenorrhoea, with appropriate dietary behaviours, regular physical activity, self-care, good social relationships and reduced stress levels. Similarly, given the negative impact of dysmenorrhoea on quality of life, it is recommended that measures should be taken to increase awareness of dysmenorrhoea and appropriate lifestyles among the female population in order to reduce its occurrence and impact [20].

In terms of specific professions, Chiu et al. [12] developed a study to investigate the impact of dysmenorrhoea on nurses, based on three main objectives. Firstly, to describe the demographic and menstrual characteristics of dysmenorrhoea; secondly, to establish the knowledge of the disorder and menstrual attitudes of nurses in the hospital habitus; and thirdly, to identify significant differences between groups and to investigate factors affecting the disorder. As a result, they found that out of a total of 420 participating nurses, 297 (70.7%) had experienced dysmenorrhoea in the previous 6 months, and significant differences were found in: age (P<0.001), marital status (P<0.001), fertility status (P<0.001), age at menarche (P<0.05), and the ratio of three rotating shifts (P<0.05) between the group with and without dysmenorrhoea. Specifically, compared to the group without dysmenorrhoea, participants with dysmenorrhoea were significantly younger (t = -3.78, P <0.001), more often single (77.78%, χ^2 = 20.03, P <0.001), had no history of childbirth (83.16%, χ^2 = 19.38, P <0. 001), and more frequently had an age at menarche <12 years (15.49%, χ^2 = 4.70, P = 0.03), as well as a higher percentage of participants with dysmenorrhoea, working a three-shift rotation (91.25%, χ^2 = 6.06, P = 0.014) [12].

The MAS (Menstrual Attitude Scale) outcome analysis revealed significant differences between the groups with respect to the consideration of menstruation as a debilitating (P <0.001) or annoying event (P <0.05), anticipation and prediction of the onset of menstruation (P <0.01) and denial of any effect of menstruation. (P <0.001). Regarding attitudes toward menstruation, after standardizing, the

highest scoring dimension among the dysmenorrhea group was "considering menstruation as a debilitating event" and "considering menstruation as a natural event," in the non-dysmenorrhea group. The lowest scoring dimension in both groups was "denial of any effect of menstruation" [12]. In conclusion, the authors focus their results on supporting nursing managers to provide adequate assistance to high-risk groups, build a caring and friendly work environment, ensuring self-care at work, improving their comfort level, increasing their job satisfaction and performance [12].

In contrast, the study by Hirata et al. [65] considered that traits related to primary and secondary sexual characteristics have a significant impact on the daily lives of women in adolescence and adulthood, including dysmenorrhoea. To this end, they performed a GWAS analysis on 11,348 Japanese female subjects, assessing a total of 22 phenotypic variables related to gynaecology, as well as significant associations for breast size, pain severity (dysmenorrhoea) and menstrual fever. Analysis of breast size identified significant association signals in CCDC170-ESR1 (rs6557160; $P = 1.7 \times 10^{-16}$) and KCNU1-ZNF703 (rs146992477; $P = 6.2 \times 10^{-9}$), and found that one third of the known associations for European ancestry were also present in the sample analysed for Japan. The eQTL data found pointed to CCDC170 and ZNF703 as functional targets of these signals, and for menstrual cramps, a then-new association was identified in OPRM1 (rs17181171; $P = 2.0 \times 10^{-8}$), with large variants in multiple tissues. Similarly, a known dysmenorrhoea signal near the NGF gene replicated in their data (rs12030576; $P = 1.1 \times 10^{-19}$) and was associated with expression of RP4-663N10. 1, a putative lncRNA enhancer of the NGF gene, while a novel dysmenorrhoea signal at the IL1 locus (rs80111889; $P=1.9\times10^{-16}$) contained SNPs previously associated with endometriosis and was most significantly associated with IL1A expression [65].

The authors analysed dysmenorrhea pain severity using linear regression analysis and identified two strongly associated loci at chr1: 115.81-115.83 Mb (top SNP: rs12030576; $P = 1.13 \times 10^{-19}$) and chr^2: 113.48-113.58 Mb (top SNP: rs80111889; $P = 1.90 \times 10^{-16}$), which were also observed for secondary dysmenorrhea phenotypes [65]. For menorrhagia (impact on QoL), a nominally significant association signal was observed at chr6: 154.33-154.46 Mb (top SNP: rs17181171; $P = 1.98 \times 10^{-8}$), which overlaps more than half of the 5' end of opioid receptor mu 1 (OPRM1) and contains 65 high LOD SNPs [65]. Three of these variants are in highly conserved intronic regions (rs3778146, rs3778150, rs9479759), but only two SNPs overlap with any epigenomic mark, and both were DNAase hypersensitivity sites (DHS) with no evidence of promoter or enhancer activity [65]. This study supports the benefits of analysing diverse phenotypes in different samples from ethnic populations, and demonstrates the advantages of using eQTL datasets composed of different tissue types. Using GWAS/eQTL colocalisation analysis, it was possible to demonstrate that the top GWAS SNPs at each of the loci identified in this study were also associated with the expression of a protein-coding gene and/or lncRNA, and that further research is needed to elucidate how these eQTLs influence human phenotypic variation [65].

A contrasting, multifactorial cut-off study is addressed by Lee et al. [14]. These authors suggest that dysmenorrhoea in later life often coexists with many chronic functional pain disorders, and these show a large-scale association with changes in the distribution of brain regions, so it is unknown whether female with primary dysmenorrhoea (PDM) show such changes. Using resting-state functional magnetic resonance imaging (fMRI) and graph-theoretic network analysis, we investigated the global, regional and modular network metrics of functional brain networks in female with PDM. No significant differences were obtained between groups with respect to age (PDM: 23.1 ± 2.27 years of age, control: 23.7 ± 2.40 years of age, $P = 0.147$), age at menarche (PDM: 12.2 ± 1.19 years of age, control : 12.2 ± 1.11 years of age, $P = 0.811$), years of menstruation (PDM: 10.9 ± 2.53 years, control: 11.5 ± 2.69 years, $P = 0.194$) or mean duration of a menstrual cycle (PDM: 29.3 ± 1.41 days, control: 29.5 ± 1.19 days, $P = 0.525$). Although women with PDM reported significantly higher scores regarding: anxiety status, anxious traits, Beck Anxiety Inventory, Menstrual Phase Pain Catastrophizing Scale (MENS) and periovulatory phase (POV), in contrast to serum gonadal hormone measurements; no significant differences were found between groups for estradiol, progesterone and testosterone concentrations during both phases [14].

In this study, we also found no significant differences between groups for metrics of global and local network efficiency of information transfer between nodes, indicating that the population examined may retain the integrity of the connectivity properties of functional brain networks, despite the presence of

maladaptive neuroplasticity. This implies that it is plausible that the absence of significant changes in the intrinsic functional architecture of the brain allows female with PDM, to maintain normal psychosocial interactions, during the pain-free follicular phase [14].

Next, and to conclude this section, the results of the systematic reviews analysed are described. In the study conducted by Latthe & Champaneira [14], they sought to identify evidence on the effectiveness of pharmacological interventions for the treatment of primary dysmenorrhoea. They found that non-steroidal anti-inflammatory drugs (NSAIDs) reduced moderate to severe pain compared to placebo, but no significant differences were found between the NSAIDs evaluated, so it is unknown whether one has a superior effect to the others [14]. For simple analgesics, aspirin was found to reduce pain in women with primary dysmenorrhoea in the short term compared with placebo, although few trials were of good quality and it is not known whether paracetamol is more effective than placebo in reducing pain [14]. However, it was possible to determine that combined oral contraceptives may be more effective than placebo in reducing pain; however, few trials were of good quality and no significant differences were found in whether or not intrauterine progestins reduced dysmenorrhoea [14].

In the systematic review by Petraglia et al. [31] on the same topic, it was reported that heavy menstrual bleeding and duration of menstrual bleeding were often associated with dysmenorrhea. Childbearing was also identified as a highly influential factor for less dysmenorrhoea, and increasing age was also associated with less severe dysmenorrhoea. Early onset of pain was associated with more severe pain, and a family history of dysmenorrhoea was associated with a significantly higher prevalence. The authors also suggest that dysmenorrhoea may be part of a somatoform syndrome, as anxiety and depression are often associated [26]. In terms of treatment, it was noted that NSAIDs are usually the first-line treatment, and if they are not sufficient alone, they can be combined with oral contraceptives (OCs) (ACOG, 2005). The authors conclude that, given the wide availability of NSAIDs, the management of dysmenorrhoea is mainly a matter of self-care [7,81, 82].

Susceptibility-associated genes

From the search and systematic analysis of studies that have identified susceptibility genes for dysmenorrhoea, its severity and its correlation with lifestyle, a total of 11 effective studies are reported, from 2007 to the present, as follows 2 in 2007, 2016 and 2017, and 1 in 2013, 2014, 2018, 2020 and 2021. The findings in relation to the identified genes, SNPs and pro-inflammatory factors are listed below, based on the aim and scope of the study, from its results and perspectives.

CYP1A1 gene (CYP1A1MspI and CYP1A1HincII polymorphisms)

In 2007, Li et al. [83] investigated how the association between passive smoking exposure and primary dysmenorrhoea is modified by the expression of two susceptibility genes, CYP1A1MspI and CYP1A1HincII. They recruited 1645 female textile workers in Anqing, China, from 1997 to 2000. To conduct the study, they collected information on their (passive) smoking exposure and primary dysmenorrhoea status, and blood samples were collected for association analysis (multiple logistic regression) between the above-mentioned polymorphisms of the CYP1A1 gene and passive smoking exposure [83].

The theoretical-physiological basis of this association lies in the ability of an individual to convert the toxic metabolites of cigarette smoke into less harmful fractions to minimize adverse health effects. Specifically, the researchers address the detoxification of PAHs (polycyclic aromatic hydrocarbons), which in humans involves two phases: Phase I, in which inhaled hydrophobic PAHs are converted mainly through arylhydrocarbon hydroxylase activity into hydrophilic ones, and Phase II, in which reactive hydrophilic intermediates, such as epoxides, are covalently bound to macromolecules, especially DNA, and may be more toxic than the original form [84]. Aryl hydrocarbon hydroxylase is encoded by the cytochrome P450 1A1 (CYP1A1) gene, a well-studied phase I enzyme and is particularly relevant to the metabolism of chemicals in cigarette smoke. This gene is highly polymorphic in the population [47,85] and its polymorphisms have been associated with its encoded enzymatic activities [86]. Its variants also play an important role in estrogen metabolism and have been linked to women's health conditions, including breast cancer and the onset of menarche [87-89].

The study by Li et al. [89] found some interesting

results; it significantly associated passive smoking with dysmenorrhoea when the population was stratified by HincIIa or MspI genotypes. When passive smoking and CYP1A1 genotypes were considered together, the strongest association was found in passive smoking women with the Ile/Ile462 polymorphism in CYP1A1HincII and C/C6235 in CYP1A1MspI. In the unexposed group, CYP1A1 genetic susceptibility alone did not contribute to a significant adverse effect, suggesting that CYP1A1 genotypes would modify the effect of passive smoking on primary dysmenorrhoea [89]. The increased risk of primary dysmenorrhoea compared to reference groups in the presence of passive smoking may be due to a reduced ability to convert toxic metabolites of cigarette smoke into less harmful hydrophilic compounds, therefore these authors demonstrated that passive smoking is associated with primary dysmenorrhoea under modification of CYP1A1 gene polymorphisms, providing evidence of the combined effects of the genetic environment and supporting the importance of assessing the role of genetic susceptibility in the evaluation of reproductive toxins because of its important implications for women's health [89].

In this context, authors such as Wu et al. [90] found that CYP2D6 and GSTM1 variant genotypes were associated with an increased risk of recurrent dysmenorrhoea [90]. And when the genotypes were considered together, an increased risk of the disease was found in women with variant genotypes in both CYP2D6 and GSTM1. Crofts et al. [91] found that variant genotypes at the HincII site were significantly associated with increased CYP1A1 gene inducibility and also observed a significant interaction between HincII polymorphism and smoking at the mRNA level [89].

In the same year, Liu et al. [92] investigated the same association, but in this case, they included a population of 1645 newly married women workers (1124 without dysmenorrhoea, 521 with dysmenorrhoea) who did not smoke or drink in the same place in China, but in the period between June 1997 and 2000. In this case, we analysed using multiple logistic regression models. It was found that passive smoking was significantly associated with dysmenorrhoea and, in addition, both the Ile/Ile462 variants in CYP1A1HincII and C/C6235 in CYP1A1MspIm were significantly associated with the disorder. When passive smoking and CYP1A1 genotypes were considered together, the statistical behaviour was very similar to that reported by Li et al. [89], where a stronger association was found in passive smoking women with Ile/Ile462 in CYP1A1HincII and C/C6235 in CYP1A1MspI than in the unexposed group, where CYP1A1 genetic susceptibility alone did not contribute to a significant adverse effect, suggesting that CYP1A1 genotypes would modify the effect of passive smoking on dysmenorrhoea [92].

CYP1A1 MspI and HincII genotypes were found to modify the association between passive smoking and dysmenorrhoea based on the investigators' research hypothesis that women passively exposed to tobacco smoke have a number of genetic susceptibility factors, including metabolic enzyme activities, which influence the levels of toxic substrates entering the blood and would further influence dysmenorrhoea [92]. Directionally, the study found that female passive smokers who had the CYP1A1 MspI variant of the C/C6235 genotype or the CYP1A1 HincII wild-type Ile/Ile462 genotype, which results in a reduction in the individual's ability to convert toxic metabolites of cigarette smoke into a less harmful hydrophilic compound, had significantly the highest risk of dysmenorrhoea compared to the reference groups. They also found that the more women were exposed to secondhand smoke, the greater the risk in the CYP1A1 MspI group C/C6235 and CYP1A1 HincII group Ile/Ile462, suggesting a dose-response relationship between secondhand smoke and dysmenorrhea [92]. Like Lu [93], the researchers showed that passive smoking is associated with dysmenorrhoea. However, this association is modified by an individual's genotype [92].

Altered expression of genes encoding cytokines

Primary dysmenorrhea may be associated with dysregulation of normal menstruation, which in response to progesterone withdrawal, depends on complex interactions between ovarian hormones and the immune system [94]. A variety of immune factors in the endometrium contribute to decidualization, menstruation and subsequent tissue repair [95]. In this context, many cytokines have been identified that could potentiate or inhibit decidualization, including IL-1, TNFa, LEFTY, bone morphogenetic proteins (BMPs), and GSF2 [94, 96]. Therefore, dysmenorrhea is considered to be caused by an exaggerated response to physiological processes at the time of menstruation and there is evidence that women with primary dysmenorrhea experience uterine hypercontractility in

the perimenstrual phase [96-98].

During contractions, uterine blood flow is compromised, resulting in relative tissue ischemia and pain. Peripheral blood analysis of dysmenorrheic women has revealed excessive synthesis and concentrations of oxytocin (OT), PGF2a, vasopressin (VAP) and IL-6 [96, 99-101]. Particularly, on the first day of menstruation, plasma vasopressin levels and PGF2a metabolites were found to be significantly higher in women with severe primary dysmenorrhea [102]. Plasma concentrations of oxytocin and IL-6 were also markedly higher in dysmenorrheic patients than in healthy volunteers during menstruation [96, 101]. According to Ma et al. [96] these mediators could increase uterine contractility [94] and play an important role in the pathophysiology of primary dysmenorrhea.

In 2013, Ma et al. [96] compared 84 gene expression profiles of common peripheral blood mononuclear cell (PBMC) cytokines in six female with primary dysmenorrhea and three unaffected controls on the seventh day before menstruation (secretory phase), the first (menstrual phase) and the fifth day (regenerative phase) of the menstrual period; using a real-time PCR array assay combined with pattern recognition and gene function annotation methods. Comparisons between women with dysmenorrhoea and normal controls identified 11 (nine up-regulated and two down-regulated), 14 (five up-regulated and nine down-regulated) and 15 (seven up-regulated and eight down-regulated) genes with a ≥2-fold difference in expression (P=0.05) in the three phases of menstruation, respectively. In the menstrual phase, genes encoding pro-inflammatory cytokines (IL1B, TNF, IL6 and IL8) were positively regulated and genes encoding members of the TGF-b superfamily (BMP4, BMP6, GDF5, GDF11, LEFTY2, NODAL and MSTN) were negatively regulated [96].

Functional annotation of the genes further revealed an excessive inflammatory response and insufficient signalling of TGF-b superfamily members with anti-inflammatory consequences, which may directly contribute to menorrhagia. In the secretory and regenerative phases, increased expression of pro-inflammatory cytokines and decreased expression of growth factors were also observed. These factors may be involved in regulating decidualisation, endometrial degradation and repair, and indirectly exacerbate primary dysmenorrhoea [96]. In this type of dysmenorrhoea, gene expression levels of proinflammatory cytokines (IL1B, TNF, IL6 and IL8) were significantly increased on the first day of menstruation, while those of anti-inflammatory cytokines (ILF5 and IL11) were significantly reduced compared to unaffected controls. Similarly, the expression of TGF-b family genes (BMP4, BMP6, GDF5, GDF11, LEFTY2, NODAL and MSTN) was down-regulated on the first day of menses [96].

Significant differences in peripheral blood mononuclear cell (PBMC) gene expression were also observed between healthy and dysmenorrhoeic women during the repair phase of the menstrual cycle. Gene annotations from the Database for Annotation, Visualisation and Integrated Discovery (DAVID) showed upregulation of inflammatory response (IL6, IL8, IL1B) and downregulation of cell proliferation (BMP4, TNFSF4, PDGFA, IL9, IL21) and wound response (IFNA2, TNFSF4, PDGFA, IL9, IL1F6). These changes suggest that prolonged acute inflammation, impaired T-cell immunity and delayed endometrial repair occur after the experience of menstrual pain [96]. In conclusion, the gene expression pattern observed in female with primary dysmenorrhoea revealed dysregulated inflammatory responses with extensive down-regulation of TGF-b family genes associated with anti-inflammatory responses and up-regulation of genes encoding inflammatory pro-cytokines. Changes in gene expression occurred not only on the first day of menstruation but throughout the cycle, and may be involved in the regulation of menstrual events (e.g. decidualisation, endometrial degradation and repair) and indirectly act to exacerbate primary dysmenorrhoea [96].

Other proinflammatory factors

Pickles et al. [103] and Lundström & Green [57] suggested that one of the factors contributing to dysmenorrhoea may be an increase in the premenstrual concentration of prostaglandins, and demonstrated that these are produced in excess in patients suffering from dysmenorrhoea [57]; this in the context of the symptoms associated with the disorder during the menstrual period [104]. Prostaglandins cause narrowing of the blood vessels supplying the uterus, resulting in abnormal contractile activity, ischaemia, hypoxia and increased sensitivity of nerve endings [59,104]. In addition to hormonal changes in the body, other factors such as diet, early age at menarche, stress, duration and severity of menstruation, and the presence of premenstrual

syndrome (PMS) may contribute to its pathological mechanism [56].

In addition, authors such as Finn [105] have suggested that menstruation could be considered an inflammatory event, as leukocyte invasion and subsequent production of inflammatory mediators are observed [56]. In response to these questions, Barcikowska et al. [56] sought to establish a complete understanding of the pathomechanism of dysmenorrhoea through a systematic review. They reported that previous research indicates the complexity of biochemical reactions between the endocrine, vascular and immune systems in the disorder, and noted that prostaglandins play an important role in its pathomechanism, while cytokines and other proinflammatory factors (in primary dysmenorrhea) are less well studied. They also noted that more and more studies are showing the efficacy of non-pharmacological methods over pharmacological ones for its treatment [56].

Specifically, progesterone has an anti-inflammatory effect and inhibits the release and activation of metalloproteinases during the secretory phase. It also affects the regulation and synthesis of prostaglandins and leukocytes [106]. After ovulation, fatty acids accumulate in the phospholipids of the cell membrane; omega-6 fatty acids and arachidonic acid are only released when progesterone levels begin to fall. The secretion of prostaglandins and leukotrienes then begins, causing uterine contractions, but also symptoms such as vomiting, tympanitis, nausea and headaches. Arachidonic acid is metabolised by two pathways, the cyclooxygenase pathway and the 5-lipoxygenase pathway. The former produces prostaglandins (PGF2α and PGE2), prostacyclins and thromboxanes. Leukotrienes are formed in the 5-lipoxygenase pathway. Arachidonic acid metabolites, such as prostaglandin PGF2α and cyclooxygenase, cause vasoconstriction, contraction of uterine smooth muscle leading to ischaemia and lowering of the pain threshold, resulting in pain [56, 107, 108].

Prostaglandins have also been shown to be associated with inflammation and are produced during menstruation. Prostaglandin F2α (PGF2α) and prostaglandin E2 (PGE2) have specific roles in the inflammatory process. PGF2α mediates the constriction of the arcuate vessels, leading to local hypoxia of the endometrial tissue, and stimulates smooth muscle contraction, which in turn promotes menstrual bleeding. The effects of PGE2 depend on the type of receptor, but may include relaxation of endometrial blood vessels, increased swelling and recruitment of leukotrienes [108]. In addition, prostaglandins may be involved in the formation of other chemokines and growth factors involved in the inflammatory response or repair process after menstruation [56, 108].

Regarding vasopressin, Barcikowska et al. [56] point out that vasopressin concentration is lower in the follicular phase and then increases during ovulation; this may contribute to an increase in uterine contractile activity and reduce uterine blood flow, which in turn may lead to ischaemia and dysmenorrhoea [99,102]. Several authors highlight the role of vasopressin in the pathomechanism of the disorder [99,102], in particular Liedman et al. [99], showed that vasopressin levels during ovulation were lower in women with dysmenorrhoea than in healthy women, whereas no significant changes were observed during menstruation. According to Strömberg et al. [102], women with premenstrual syndrome or dysmenorrhoea had higher vasopressin concentrations than women without similar symptoms, but other studies do not confirm the role of vasopressin in dysmenorrhoea [56,109]. In these cases, the authors compared vasopressin levels in women with dysmenorrhoea and healthy women and found that there was no significant difference in levels between the two groups [56,109].

Val66Met polymorphism of the BDNF gene

According to Lee et al. [110], brain-derived neurotrophic factor (BDNF) is considered a modulator of pain due to its involvement in activity-dependent synaptic plasticity within pain circuits. With a pro-nociceptive role, BDNF generates the hyperalgesic responses in inflammatory models of pain [111] and also plays a key role in the production of central sensitisation, contributing to chronic pain conditions [111,112]. It may also be involved in stress-related mood disorders [63], such as major depression [110].

Conditions such as stress [63] or chronic pain [113] reduce BDNF expression in brain structures that control mood and have been shown to mediate the effects of sex hormones in the hippocampus. Therefore, the interaction between estrogen and BDNF in this brain region may underlie menstrual cycle-related problems [114,115]. In this regard, Lee et al. [110] reported that the Val66Met (rs6265) BDNF polymorphism results in the substitution of

methionine (Met) for valine (Val) at codon 66 of the proBDNF protein, and the Met allele leads to reduced activity-dependent BDNF secretion from neurons and impaired BDNF signalling [116]. It may therefore be involved in both chronic pain conditions and mood disorders [110].

In this regard, Lee et al. [110] investigated and genotyped the Val66Met (rs6265) BDNF polymorphism in 99 Taiwanese women with primary dysmenorrhea (PDM, aged 20-30 years) and 101 age-matched healthy female controls. We investigated whether the polymorphism might be associated with an increased risk of PDM in Asian individuals and concluded that PDM homozygotes Met/Met might have a higher perception of menstrual pain and more negative emotions compared to PDM individuals carrying the Val polymorphism. Similarly, the relationships between the Val66Met BDNF polymorphism genotypes and pain-related clinical manifestations, emotions in PDM and psychophysical assessments (pain sensitivity to experimentally induced thermal cutaneous pain) were investigated. We found that the frequency of the Met allele of the polymorphism was significantly higher in the PDM group. In addition, BDNF Met/Met homozygosity had a significantly stronger association with dysmenorrhoea of primary origin compared to Val carrier status. These results also suggest the Val66Met BDNF polymorphism as a possible regulator of menstrual pain and pain-related emotions in PDM [110].

In 2016, Wei et al. [64] reported structural and functional connectivity (FC) changes in the periaqueductal grey (PAG) of individuals with primary dysmenorrhea. Since brain-derived neurotrophic factor (BDNF) acts as a pain modulator within the PAG and the Val66Met BDNF polymorphism contributes to PDM susceptibility, an imaging genetics study was proposed to investigate the influence of the single nucleotide Val66Met BDNF polymorphism and whether this genotype is involved in downstream pain modulatory systems in the context of the PAG-embedded FC pattern. The study involved 56 women with PDM and 60 controls, who underwent resting-state functional magnetic resonance imaging (fMRI) during the menstrual and periovulatory phases, with parallel blood sampling for genotyping [64].

The results of these authors suggest that the Val66Met BDNF polymorphism is associated with different functional expressions of downstream pain modulatory systems. Furthermore, PAG FC patterns in pain-free controls were observed to be altered in a genotype-specific manner in women with PDM. Such resilient brain dynamics may underpin individual differences and shed light on vulnerability to chronic pain disorders in PDM subjects [117]. Similarly, they note that the Val66Met BDNF polymorphism is associated with the differential functional expression of downstream pain modulatory systems in the context of PAG-seeded PK. Val/Val PDM subjects show more adaptive neuroplasticity, whereas Met/Met PDM subjects show more maladaptive neuroplasticity. Such resilient brain dynamics may underpin individual differences and shed light on the vulnerability of PDM-affected subjects to chronic pain disorders [117].

Similarly, in 2018, Low et al. [118] genotyped the Val66Met BDNF SNP Val66Met in 80 women with primary dysmenorrhoea (20 Val/Val, 31 Val/Met, 29 Met/Met) and 76 healthy female controls (25 Val/Val, 36 Val/Met, 15 Met/Met). Multiscale entropy analysis (MSE) was applied to neural source activity estimated from resting-state magnetoencephalography (MEG) signals during the pain-free state. Changes in brain complexity were found to be associated with interactions between the Val66Met BDNF polymorphism and the experience of menstrual pain; in healthy female controls, Met carriers (Val/Met and Met/Met) showed lower brain complexity than Val/Val homozygotes in large brain regions, suggesting a possible protective role of Val/Val homozygosity in such complexity. However, after experiencing long-term menstrual pain, complexity differences between different genotypes in healthy controls were significantly reduced in PDM women, particularly in the limbic system, including the hippocampus and amygdala [118].

These authors also found that, first, the Val66Met BDNF polymorphism (Met / Met homozygosity) is a potential genetic risk factor associated with primary dysmenorrhea, which is consistent with previous studies [64,110]. Second, their findings suggest that long-term experience of menstrual pain alters the effects of the Val66Met BDNF polymorphism on brain complexity. When comparing brain complexity in women of different genotypes with or without menstrual pain, a characteristic trend with considerable genotype-specific complexity differences was identified in CON (control) women, where Met (Val/Met and Met/Met) carriers showed much lower

brain complexity compared to Val/Val CONs. However, complexity differences were significantly reduced in PDMs, suggesting the role of chronic recurrent pain attacks on brain complexity. Third, they observed pain-associated changes in brain complexity in limbic regions, particularly the hippocampus and amygdala, in women with the same Val66Met BDNF genotype. Overall, their findings suggest that pain experience overwhelmingly influences the effect of the Val66Met BDNF polymorphism on brain complexity, and also highlight the potential use of resting-state brain complexity for the development of new therapeutic strategies in patients with chronic pain [118].

In the same vein, a study by Li et al. [15] investigated the associations between Val66Met BDNF polymorphisms, menstrual pain severity and hippocampal volume in young subjects with PDM. We recruited 115 subjects with PDM, including severe cases (n = 66), moderate cases (n = 44), and 117 female (aged 20-30 years) as a control group (CON), for both polymorphism genotyping and MRI examination. Evaluation at the hippocampal volume level included analysis at different anatomical resolutions, i.e. total hippocampal volume, hippocampal subfields and volumetric analysis using voxel-based morphometry (VBM). These authors investigated the means by which Val66Met BDNF polymorphisms contribute to structural plasticity of the hippocampus and its subfields, and how these effects are modulated by pain severity in PDM subjects. The aim is to elucidate genotype-specific morphometric dynamics that may shed light on individual differences in long-term stress-induced hippocampal plasticity [15].

This study postulated that interactions between the Val66Met BNDF polymorphism, PDM severity and its effects on hippocampal volume could be used as a basis for investigating the mechanisms that predispose individuals to chronic pain disorders. This was achieved by adopting a strategy that included hippocampal volumetry at different levels of structural resolution, i.e. total volume, subfields and voxel-based morphometry (VBM) volumetric analysis. No main effects of group, genotype or group-genotype interactions on bilateral total hippocampal volumes were observed. Significant interactions between PDM severity and Val66Met BDNF genotype were observed in the right whole hippocampus, subiculum and molecular layer. Post-hoc analysis showed that the mean hippocampal volume of subjects with moderate PDM and Val/Val homozygotes was larger than that of subjects with severe PDM. Similarly, the right hippocampal volume was larger in the Val/Val group than in the Met/Met group, particularly in the right posterior hippocampal region [15].

Dose-response analysis revealed a positive dose-dependent relationship between the Val allele and volume of the right whole hippocampus, subiculum, molecular layer and right posterior hippocampal region as defined by VBM only in the moderate PDM subgroup. These findings suggest that PDM subjects with Val/Val homozygosity are resistant to moderate intermittent pain-related stress, whereas PDM subjects carrying Met are susceptible, and provide evidence for a dose-dependent protective effect of the Val allele on hippocampal structure. However, in Val variant cases, these effects were modulated according to the severity of menstrual pain. In addition, these results suggest that the BDNF Met/Met polymorphism may render an individual susceptible to deleterious effects (e.g. hippocampal volume) resulting from adverse early life events (PDM in the current study), whereas the BDNF Val/Val polymorphism appears to confer protective effects at the hippocampal level [15].

The A118G polymorphism of the mu-opioid receptor (OPRM1)

According to Wei et al. [119] the experience of pain and clinical response to opioid analgesics varies between individuals, and the analgesic effects of opioids are mediated largely by the mu-opioid receptor (OPRM1) in the central nervous system [120]. The single nucleotide polymorphism A118G causes a substitution of adenine (A) for guanine (G) at codon 118 in the human OPRM1 gene and is associated with reduced expression of the gene. It is also associated with hypersensitivity to pain [121] and increased use of analgesics for clinical purposes [122]. Despite its importance, it was only in 2017 that the question of how the A118G OPRM1 polymorphism interferes with the descending pain modulatory system (DPMS) to relate to individual pain experience was addressed. As a proposal, Wei et al. [119] conducted an imaging genetics study (using neuroimaging as an endophenotypic test to assess genetic associations, with pain as an environmental stress); investigating the neural network mechanisms of the polymorphism for central pain modulation in women - otherwise healthy - but diagnosed with primary dysmenorrhea (PDM) [119].
The aim of this study was to investigate whether

differences in functional connectivity (FC) of the DPMS between A118G OPRM1 polymorphisms could provide a possible explanation for differences in pain experience in patients. The study involved 61 people with PDM and 65 controls who underwent functional magnetic resonance imaging (fMRI) at rest, during menstruation and ovulation. Blood samples were also taken for genotyping, and three aspects of pain experience were examined: mnemonic pain (remembered general menstrual pain), present pain (spontaneous menstrual pain) and experienced pain intensity (thermal pain) [119].

As a result, G allele carriers were found to have functional hypo-connectivity between the anterior cingulate cortex (ACC) and in the periaqueductal grey (PAG) compared to AA homozygotes. Furthermore, G allele carriers lost correlation with spontaneous pain experience and exhibited dysfunctional DPMS via PAG-seeded FC dynamics. Thus, the OPRM1 A118G-DPMS interaction was considered a plausible neurological mechanism underlying individual differences in pain experience. The authors believe that such differences may be due to different pain processing mechanisms and neuromodulators loaded by genotypes in the brain, particularly the DPMS system [119].

Taken together, the data obtained suggest active cortical modulation of current (momentary) menstrual pain and may explain why AA homozygotes rated their current pain experience sub-significantly lower than G allele carriers [119]. In contrast to some previous genetic studies of the A118G OPRM1 polymorphism, no differences in pain-heat thresholds were observed. There are several explanations for these inconsistencies, including sex ratio differences (sex by genotype interaction appears for heat pain, [123]), pain modalities (neither electrical stimulation [121] or pressure [123], ethnicity (Asians differ from Caucasians in G allele variability [124] and in the phenotype of the A118G OPRM1 polymorphism [119,125].

To the authors' knowledge, this is the first study to provide new insights into the previously unexplored neurodynamic influences of the A118G OPRM1 polymorphism in PAG-based DPMS PKs. Such genetic variations shape the functional organisation of DPMS and may predict or underpin differential analgesic efficacy (responsive or non-responsive) [126] and may ultimately contribute to susceptibility to the development of chronic pain late in life in PDM subjects [64,119].

The SNP rs7523086 colocalized in the NGF (nerve growth factor) gene

To better understand variation in dysmenorrhea pain severity and identify genetic predisposing factors, Jones et al. [68] conducted a genome-wide association study (GWAS) of dysmenorrhea pain (self-reported) in participants from the 23andMe cohort [127]. This study investigated an association at the nerve growth factor gene locus in a cohort of women of European ancestry (n = 11.891) aged 18-45 years who rated their dysmenorrhoea pain as moderate. Their findings suggest that pain severity is partly determined by the genetic component, as the NGF gene is known to play an established role in chronic pain disorders, suggesting that the gene may be an important mediator of gynaecological and/or pelvic visceral pain [68].

The presence of the risk allele corresponded to a predicted 0.1-point increase in pain intensity on a 4-point ordinal pain scale (1q13.2, neutrophin colocalised with NGF).Although the putative effects on NGF function and/or expression remain unknown, the genetic variation correlated and colocalised with active epigenetic marks in adipose, ovarian and aortic tissue expression levels of non-coding RNA flanking the NGF gene, explaining 0.48% of the observed variance [68]. Similarly, two previously reported modulators of dysmenorrhoea severity were identified: age [128,129] and body mass index (BMI) [130]. Increased pain was correlated with younger age (P 5 1.2 3 10217) and lower BMI (P 5 3.8 3 10225). The effect estimates for age and BMI were only slightly stronger than the main genetic variant, explaining 0.62% and 0.52% of the observed variance in the endpoint, respectively [68]. Similarly, participants who reported extreme pain from dysmenorrhoea were more likely to report having endometriosis, polycystic ovarian syndrome, depression and other psychiatric disorders [68].

The authors concluded that the common genetic pleiotropy between dysmenorrhoea, painful gynaecological conditions, depression and other related disorders is an important area of research to better understand these conditions. The current GWAS data for these conditions have not identified a signal at the NGF locus [70,131], which may be because these studies were designed to identify genetic factors that specifically influence disease risk

rather than disease-associated pain severity [68]. Similarly, the authors recommend that further experimental validation exploring and defining the biological mechanisms of the role of the NGF gene in dysmenorrhoea pain severity is key to repurposing analgesics targeting the NGF pathway for this disorder and related conditions [68].

Conclusion

Despite the important findings on the incidence and causality of dysmenorrhoea (generally primary or PDM) that have been identified in recent years, it is clear that the heterogeneity of the studies, the shortcomings in the establishment of protocols and baselines in their development, as well as the lack of systematicity to ensure their reproducibility over time and in different populations, affect the potential of their results and reduce their impact in terms of global applicability. The implementation of new-generation sequencing techniques, genetic imaging studies and the preservation of blood tests as a discriminatory factor could, in the short term, make it possible to establish causality and therefore treatment options for different ethnic groups, taking into account their lifestyles and habits, which, in the opinion of this researcher, are often underestimated and, given the findings in the literature, appear to play an important role in the incidence and severity of pain associated with dysmenorrhoea. Cultural recognition that the pain and disability caused by menstruation is not part of a natural or normal symptomatology will allow us to provide treatment and improve the quality of life of women affected by this painful and debilitating disorder.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of views and not that of the institution to which they belong.

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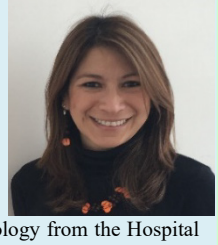
Mev Dominguez Valentin



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Scoping Review Article | *Medicine*

Effectiveness of educational interventions to reduce healthcare- associated infections in adult intensive care units

Efectividad de las intervenciones educativas en la disminución de infecciones asociadas al cuidado de la salud en la unidad de cuidados intensivos para adultos

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Abstract

Healthcare-associated infections (HAIs) represent a serious threat to patients admitted to hospitals and particularly to ICUs, as they contribute to increased mortality, prolonged length of stay and consequently increased healthcare costs. The aim of the present scoping review was to evaluate the effectiveness of educational interventions for the reduction of these infections in the adult ICU. A systematic literature search was conducted from December 2022 to March 2023, making use of official electronic databases such as PubMed, SCOPUS, CINAHL and Cochrane Database of Systematic Reviews; the key terms used for the search were the following: "Healthcare Associated Infections"; "educational interventions"; "intensive care unit" in all possible combinations and making use of the Boolean operators "AND" and "OR"; the application of the PRISMA methodology allowed a final screening of ten[MOU2] (10) studies on which the present review was based. In the selected studies, it was evident that education was essential and should be shared between multidisciplinary care teams, patients, their families, and caregivers. Statistical significance was found in two studies that demonstrated a reduction in HAIs. Despite considerable variation in the duration and type of educational intervention, the importance of establishing continuing education to maintain intervention results.

Resumen

Las infecciones asociadas al cuidado de la salud (IAAS) representan una amenaza para los pacientes que ingresan a hospitales y especialmente a UCI, al contribuir en el aumento de la mortalidad, prolongación de su estancia e incremento en los costos. El objetivo de este trabajo fue evaluar la efectividad de las intervenciones educativas para la reducción de las IAAS en la UCI de adultos. Se realizó búsqueda bibliográfica entre Diciembre 2022 - Marzo 2023 en las bases de datos PubMed, SCOPUS, CINAHL y Cochrane Database of Systematic Reviews. Términos claves usados en todas las combinaciones: “Healthcare Associated Infections”; “educational interventions”; “intensive care unit”. Mediante la metodología PRISMA se obtuvo un resultado de 10 estudios [MOU1]. En ellos se evidenció que la educación es esencial y debe ser compartida entre los equipos de cuidado multidisciplinarios, los pacientes, familias y los cuidadores; además hubo significancia estadística en dos estudios que demostraron una reducción en las IAAS. A pesar de la variación considerable en la duración y el tipo de intervención educativa, se resalta la importancia de establecer la educación continua para mantener los resultados de la intervención y lograr mejoras significativas en los resultados clínicos.

Introduction

Healthcare-associated infections (HAIs), also known as nosocomial or hospital-acquired infections (HAIs), are a risk to any patient receiving care from healthcare workers [1]. Infectious processes acquired while hospitalised or within 72 hours of discharge, although this can be extended to 12 months following discharge [2]. These infections are caused by microorganisms that can be recognised by clinical and/or microbiological manifestations that depend on the pathogen, the site of infection and the condition of the host; in some specific cases, they correlate with surgical procedures such as prosthesis placement [3]. These infections can be primary or secondary, with primary infections being more common, occurring mainly in intensive care units (ICUs) and associated with central venous catheter (CVC) insertion [4].

The complications caused by these infections have multiple consequences for the patient, both in terms of morbidity and future living conditions due to possible disability, in addition to the incalculable social costs due to the impact on the family and work environment. For healthcare systems in particular, they represent a high cost in terms of the care that must be provided due to prolonged hospitalisation, the use of antibiotics as a result of bacterial resistance, diagnostic tools, medical assessments and possible new interventions [5].

Worldwide, 5-10% of patients in countries with advanced health care facilities acquire this type of disease. In the United States, catheter-associated bloodstream infections (CA-BSTIs) were the most common type of external device-associated infection (48.1%) between 1995 and 2001 [6]. On the other hand, between July 2005 and May 2008, Staphylococcus aureus was the most common pathogen associated with serious bloodstream infections [7]. Exact figures on the burden of these infections are not available for Latin America. However, countries such as Brazil, Chile and Mexico are developing research to characterise the problem in order to develop mitigation strategies [6].

In Colombia, according to the report presented by the National Institute of Health for the year 2020, the Adult and Neonatal Intensive Care Units were the services reporting the highest number of such cases [5]. In terms of type of infection, catheter-associated bloodstream infections (CA-BSTI) were the most common (48.1%), followed by mechanical ventilator-associated pneumonia (28.2%) and symptomatic catheter-associated urinary tract infections (CA-UTI) (22.8%) [5]. Given the high number of infections associated with the use of these devices, a number of strategies have been developed to prevent them. Interventions include the creation of plans tailored to the needs of each patient, with daily measurable objectives that engage both service staff and patients, relatives and carers [8]. On the other hand, in 2005, the Institute for Healthcare Improvement (IHI) identified the need for prophylactic measures such as hand hygiene, barrier precautions and chlorhexidine antisepsis [9].

In this context, Fox et al. [10] developed a protocol that included a chlorhexidine gluconate hand hygiene technique, which was disseminated to ICU nurses through a 10-week educational process. They achieved a reduction in bloodstream infections from 60 to 87% over a 12-month period [10]. Despite the protocols developed to reduce the incidence of healthcare-associated infections, research shows that their rates are still high, as are the secondary complications they cause. For this reason, we considered it necessary to carry out an in-depth study of various bibliographical sources on the way in which these protocols are disseminated among the health professionals responsible for these procedures and on the effectiveness of their application as preventive measures to control the development of infections. In view of the above, it was decided to carry out a scoping review study [11], whose aim was to determine the effectiveness of educational interventions in the reduction of HAIs in adult intensive care units.

Methods

Protocol and registration

The study was conducted according to the Preferred Reporting Item Statement for Scoping Reviews (PRISMA-ScR) guidelines [12]. We chose to review and include the protocol, which was validated by the Prospective International Register of Systematic Reviews (PROSPERO) (registration number: CRD42020172173) and published in BMJOpen [13]. A scoping review was chosen because it is a review that identifies, summarises and appraises the existing evidence in the area of study. This type of review provides an overview of the object of study, leading to the identification of gaps, new research opportunities, limitations and strengths of published studies, and implications for clinical practice [11,12].

Eligibility criteria

For the purpose of this work, we searched for studies in English and Spanish relevant to the field of healthcare associated infections, each characterised by the use and combination of the following keywords: "healthcare-associated infection"; "educational interventions", with the greatest number of variants and opportunities, including studies of patients of all ages admitted to adult intensive care units (ICUs), regardless of length of stay. Systematic reviews, randomised clinical trials, observational studies and scoping reviews from the last decade (2013-2023) were selected.

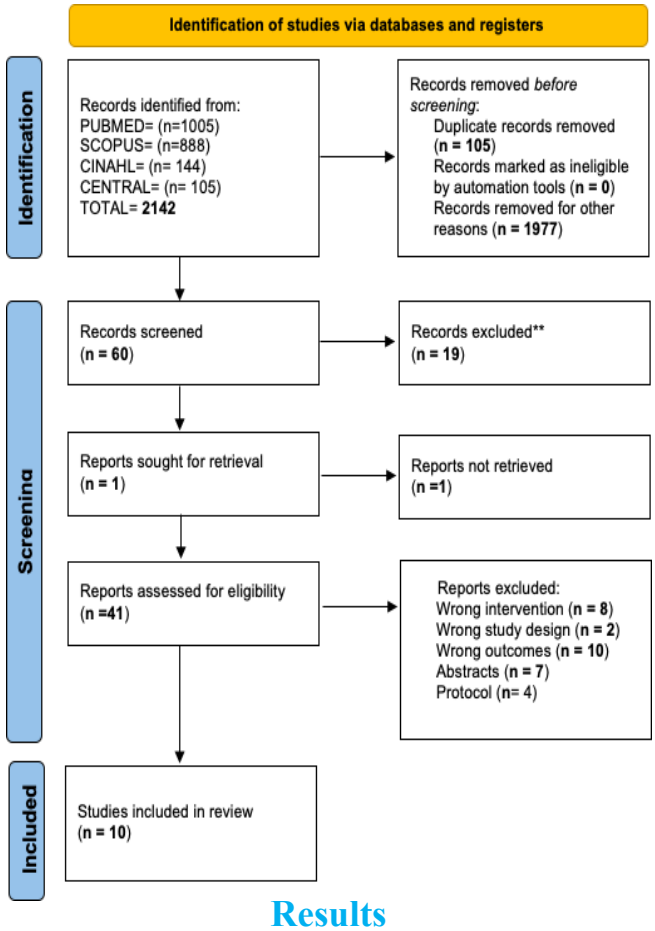
Search strategies

The search was conducted in four specialised electronic databases, PubMed, SCOPUS, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL), in English and Spanish. Duplicate trials were removed and the remaining trials were imported into the online reference management software Mendeley. The search equation was structured using the following keyword and Boolean combinations: "healthcare-associated infections" OR "nosocomial infections" OR "hospital-acquired infections" OR "iatrogenic infections" OR "central venous catheter insertion" OR "healthcare-associated disease". Associated Disease" AND "Educational Interventions" OR "ICU Infection Prevention and Control Education" OR "ICU Infection Control Training" OR "Educational Interventions to Prevent HAIs" OR "Educational Interventions to Reduce ICU Infection Rates" OR "Healthcare Personnel Education to Prevent ICU-Acquired Infections" AND "Intensive Care Unit" OR "Intensive & Critical Care Unit".

Data extraction

A total of 2142 studies were retrieved from the four databases and duplicate studies (105) were discarded. The title and aims of each article were then checked for compatibility with the aim and population of the review. After this initial filtering, 1977 articles were discarded. The remaining 60 articles were re-checked for title, aim, year of publication, abstract and type of study; after checking that they met the eligibility criteria, 19 articles were excluded.For the 41 articles obtained, a standardised form was created that included: author (first author only), year of publication, study design, characteristics and number of participants, details of intervention and control, and results of each study. The authors carried out the analysis of the form independently, comparing the results of both, and any discrepancies found were resolved by discussion. As a result of this analysis, 29 articles were discarded, eight because they did not correspond to the type of intervention targeted by our research, two (2) because of the type of publication, 10 because they did not correspond to interventions in ICUs, and seven (7) because of the abstracts. Finally, 10 studies were included in the present review (see Figure 1).

Figure 1. PRISMA flowchart for literature search, screening and selection criteria



Results

This scoping review presents the results of the studies found on the effectiveness of educational interventions to prevent healthcare-associated infections in adult intensive care patients. The studies on which this review is based (Table 1) also evaluated interventions included in both basic and special protocols, to provide a multidisciplinary view.

Table 1. Characteristics of studies in the scoping review

Title and aim	Sample	Results		Authors
		Causes related to infections	Strategies used	
Title: Evaluation of the nurses' level of knowledge regarding hand hygiene and healthcare-associated infections: a survey. **Aim:** To evaluate nurses' knowledge of hand hygiene and healthcare associated infections (HAIs) to identify their educational needs.	236 nurses were part of a healthcare-associated infection management education programme. The study was conducted between February and June 2018.	Inadequate nurse knowledge about preventing healthcare associated infections can hinder prevention.	The training programme lasted 10 hours. A theoretical part of 8 hours (4 hours per day) and a practical part of 2 hours (1 hour per day). The strategy used was videos and practical demonstrations of hand hygiene.	Nedelcu et al. [14]
Title: Is 2- person urinary catheter insertion effective in reducing CAUTI? **Aim:** Reduce urinary catheter-associated infection rates by implementing a 2-person urinary catheter insertion protocol + checklist or nurse + staff trained in sterile technique and urinary catheter insertion.	A two-person PICU team proposed by the nursing leadership team and the CAUTI committee in two ICUs.	-Problems in maintaining aseptic technique during insertion and for the duration of catheterisation. -Inadequate use of the urinary catheter refill protocol	Application of the checklist through the 4 E's . Engage: (Commitment) . Educate . Execute . . Evaluate The prevention package has been applied: use of urinary catheters for appropriate indications, sterile technique during insertion, proper maintenance and removal when not needed. and removed when not required.	Fletcher et al. [15]
Title: Implementation of central line- associated bloodstream infection prevention bundles in a surgical intensive care unit using peer tutoring. **Aim:** Reduce CVC-associated infections in a tertiary hospital surgical intensive care unit.	Conducted in the surgical ICU of a 767-bed tertiary hospital, it compared bloodstream infection rates 9 months preoperatively, 6 months postoperatively and 9 months postoperatively.	_____	Bundle education: -Insertion: hand hygiene, maximum barrier strategies during CVC insertion, skin preparation and cleansing with chlorhexidine, avoid femoral insertion if possible. - Maintenance Feedback - regular meetings Checklists	Park et al. [16]

Table 1. Continuation

Title and aim	Sample	Results		Authors
		Causes related to infections	Strategies used	
Title: Prevention of device-related healthcare-associated infections. **Aim:** Review strategies to prevent device-associated bloodstream and urinary tract infections.	Not applicable. This is a systematic review.	Colonisation at the catheter insertion site, with migration of organisms along the external surface of the catheter, is the most common source of bloodstream infections, especially during the first week of catheterisation. The following aspects were considered: i) direct contamination of connectors/hubs resulting in internal colonisation for at least one week; ii) less frequently, catheters can be seeded haematogenously from another source of infection and iii) from contaminated intravenous fluids (iv).	Prevention strategies: 1. Basic, consisting of: i) introduction; ii) maintenance; and iii) renewal/withdrawal. 2. Special, to be considered only when bloodstream infections are not controlled by the basic strategies.	Septimus et al. 17]
Title: A compendium of strategies to prevent healthcare-associated infections in acute care hospitals: 2014 updates.**Aim:** Reduce urinary catheter- provide hospital ICUs with practical, expert guidance to help prioritise and implement their HAI prevention efforts.	Not applicable. It is a compendium	_____	Core prevention strategies identified by: i) urinary tract infections, ii) Clostridium infections, iii) surgical site infections, iv) blood stream associated infections, v) methicillin resistant *Staphylococcus aureus* infections, vi) ventilator associated pneumonia. The strategy to educate healthcare workers on infection prevention, including alternatives to catheters, handling of indwelling catheters, and insertion, handling and removal procedures is being implemented.	Yokoe et al. [18]

Table 1. Continuation

Title and aim	Sample	Results		Authors
		Causes related to infections	Strategies used	
Title: Evidence-based measures to prevent central line-associated bloodstream infections: a systematic review. **Aim:** To identify evidence-based care for the prevention of central line-associated bloodstream infections in adult patients who are hospitalised in intensive care units.	Not applicable. This is a systematic review.	_____	Primary care packages including: i) safety education/culture or organisational strategies; ii) hand hygiene, maximum barrier precautions during CVC insertion, skin preparation with chlorhexidine cleanser, avoidance of femoral CVC insertion	Perin et al. [19]
Title: Use of a daily goals checklist for morning ICU rounds: A mixed-methods study. **Aim:** To understand the perspectives and attitudes of clinicians in an intensive care unit regarding the use of a daily target checklist during rounds.	Not applicable. It is a compendium	_____	Implementation of a daily individualised checklist to identify new patient care issues.	Centofanti et al. [20]
Title: Identifying management practices for promoting infection prevention: Perspectives on strategic communication. **Aim:** Identify and describe information sharing practices used to support the prevention of healthcare associated infections (HAIs).	18 hospitals in the US between 2017 and 2019, and 188 administrative leaders and clinical clinical staff.	_____	Telling stories	McAlearney et al. [21]
Title: Prevention of Central Line-Associated Bloodstream Infections Through Educational Interventions in Adult Intensive Care Units: A Systematic Review. **Aim:** To evaluate the impact of educational interventions on CLABSI rates in adult intensive care units. The relationship between effectiveness and various characteristics of educational programmes.	27 intervention trials of central line insertion or maintenance or both. In adult intensive care units with documentation of CLABSI incidence expressed per 1000 catheter days.	_____	Simulation courses; checklists; regular follow-up and multidisciplinary interventions.	Foka et al. [22]

Table 1. Continuation

Title and aim	Sample	Results		Authors
		Causes related to infections	Strategies used	
Title: International good practices on central venous catheters' placement and daily management in adults and on educational interventions addressed to healthcare professionals or awake/outpatients. Results of a scoping review compared with the existent Italian good practices. **Aim:** Review existing international literature on the placement and management of CVCs in adults and compare with published best practice.	Not applicable. It is a scoping review	_____	They describe different interventions in the four phases: assessment; introduction; maintenance; phasing out; interventions to improve implementation and sustainability; Maintenance; Phasing out; Interventions to improve implementation and sustainability. On-the-job training programmes and courses; audit and continuous training through continuous feedback to all health workers and blended learning practices.	Mastrandrea et al. [23]

Of the studies analysed, 50% used prospective designs, and the systematic reviews examined the effectiveness of educational interventions to prevent nosocomial infections, mainly in intensive care units, as a result of CVC insertion. Thirty percent of the studies analysed the probable causes of infections, with inadequate knowledge of infection prevention and poor application of antisepsis protocols being the main causes.

Discussion

This scoping review examined in detail the studies on educational processes and their effectiveness that have been carried out on staff in healthcare institutions, particularly in adult intensive care units, to achieve appropriate use of protocols as a measure to reduce rates of infection associated with nosocomial disease. The results indicate the use of a variety of educational techniques; however, little research has determined the effectiveness of this educational process. These HCAIs represent undesirable outcomes for healthcare institutions and also have important consequences for patient outcomes, such as increased suffering and length of stay, factors that lead to higher healthcare costs, morbidity and mortality [24,25]; for example, the World Health Organization indicates that they are responsible for approximately 40000 deaths per year [26].

In ICUs, the risk of HAIs is increased compared to other services, reaching a prevalence of 20.32% as reported in the 2018 EPINE study [27]. Reasons for this increase include: *i*) the presence of a greater number of multidrug-resistant microorganisms; *ii*) the frequent use of invasive techniques; *iii*) the use of antimicrobials for long periods of time; *iv*) the use of immunosuppressive treatments; and *v*) the presence of a wide range of pathologies in critically ill patients [28]. Among the objectives proposed for this review, it was important to characterise the causes associated

with the production of HAIs. In this regard, Wisplinghoff et al. [2] in the United States evaluated the epidemiological characteristics of bloodstream infections and found that 50.5% of them occurred in the ICU. In terms of microbial isolation, this study showed that 87% were monomicrobial, with 65% caused by gram-positive microorganisms, 25% by gram-negative microorganisms and 0.9% by fungi.

In a similar study carried out by Li et al. [29], they identified coagulase-negative staphylococci (CoNS) (31% of isolates), *Staphylococcus aureus* (20%), enterococci (9%) and Candida (9%) as the most common microorganisms. The most important finding was that the proportion of methicillin-resistant S. aureus, vancomycin-resistant enterococci and *Escherichia coli* with resistance to ampicillin, piperacillin and ampicillin-sulbactam was significantly higher in the ICU than in other services. This information is crucial, as knowledge of local patterns of species distribution and infection resistance provides an adequate basis for empirical antibiotic therapy, since inappropriate antibiotic therapy increases mortality by 30-60% in ICU patients with bloodstream infections [30]; therefore, appropriate medical management of infections is part of the HCAI control programme.

With regard to the identification of interventions used to reduce HAIs in ICUs, another of the objectives proposed in this study, many international guidelines have been published with numerous proposals aimed at improving and disseminating good patient care practices. Regarding strategies, Mastrandrea et al. [23], Septimus et al. [17] and Yokoe et al. [18] agree in dividing them into basic and specific strategies; the former correspond to barrier actions applied at all stages of device management, insertion, maintenance and disposal, which should be constant in all healthcare institutions, while the latter are recommended for use when infections cannot be controlled with basic care. However, researchers such as Perin et al. do not follow the division proposed above, but present the five basic elements for HCAI prevention, including basic and special care [19].

We agree with the aforementioned researchers on the importance of the implementation of barrier protocols as an effective way to prevent HAIs; in this sense, in the present study, it was observed that the suggestions made by Pronovost et al. [8], Centofanti et al. [20], and later by Fletcher et al. [15], regarding the implementation of barrier protocols through the development of checklists based on daily goals, is an excellent strategy to prevent errors of omission and reduce errors of execution. These studies highlight the positive outcomes achieved by involving all health care staff, family, carers and the patient in the implementation of these interventions.

In 50% of the articles selected for review, researchers emphasise the importance of educational interventions for healthcare workers, mentioning education as part of a prevention package that includes safety culture and organisational strategies [19,22,23,31]. This, combined with effective education, is a practical means of monitoring standards and influencing change. These programmes should be complemented by indicators for regular monitoring, a detailed plan with concrete actions and feasible and measurable alternative solutions for outcome evaluation [32].

When organising educational programmes for healthcare workers, it is important to ensure that they are aware of their role in the production and transmission of healthcare associated infections during the performance of their activities, including patient care [33]. The type(s) of educational intervention(s) varied in the studies reviewed. Most of them used a combination of different modalities, as described by Foka et al. [22]. Among the forms of educational intervention presented in the context of infection prevention, although little documented, was the inclusion of stories and narratives, a common methodology in health education settings other than the context of the present study [34].

In North America, Europe and Asia, this technique has been used as a valuable tool to educate health professionals about patient safety [35] and has been shown to be particularly effective by focusing on narratives of realistic situations and involving the listener in the education [36]. Similarly, McAlearney et al. argue that the increased impact of information shared in this way occurs because it evokes emotion, educates and celebrates success [31]. Analysing the effectiveness of the educational interventions in the selected studies was complex because, as mentioned above, half of them described the strategies used but did not evaluate the effectiveness of these interventions. Only two studies were identified. In the study by Nedelcu et al. [14], following a training programme on hospital infection prevention, the authors assessed the level of knowledge acquired by nurses in specific areas of hand washing, disinfection and sterilisation; they found that, despite the training,

almost 68% of nurses had inadequate knowledge of these topics and 39% of them had insufficient knowledge. Although this study analysed the final outcome of the educational intervention, its effectiveness could not be evaluated because it did not include a pre-assessment of the level of knowledge of the professionals prior to the educational process.

On the other hand, Park et al. [16], through a prospective intervention in the ICU, developed an educational programme for the prevention of CVC-related infections, in contrast to the work of Nedelcu et al. [14]. These researchers evaluated three times: before the intervention, during the intervention, and nine months after the intervention; in addition, they continued to record CVC-related infection rates. The results showed a significant reduction in infections from 6.9% in the pre-intervention period to 2.4 and 1.8% in the intervention and post-intervention periods, respectively. At the three-year follow-up, infection rates were reduced to 3.0-5.4 infections per 1000 catheter days over three years. Based on the results, the authors highlight the importance of maintaining and expanding educational intervention strategies over the long term. For them, learning by teaching or peer tutoring is one of the most effective educational methods because it is participatory [16].

According to this study, it has not been possible to determine which is the most effective educational intervention to reduce healthcare associated infections, because although there are several intervention models, only one of them analyses their effectiveness. Therefore, this gap offers the possibility of developing research that not only implements several of the proposed methods in educational interventions, but also uses surveys to assess knowledge before and after the intervention, in order to compare the results obtained between them and thus determine the effectiveness of each one. One point on which the reported research agrees is the importance of regular follow-up and multidisciplinary interventions to maintain the effect and rate of reduction achieved by the intervention [37]. The reported research agrees on the importance of regular follow-up and multidisciplinary interventions to maintain the effect and rate of reduction achieved by the intervention [37].

Conclusion

This scoping review found that bloodstream infections were the most common HAI, closely followed by urinary tract infections and those associated with ventilator use. Despite the variety of educational approaches, our study found it difficult to identify the most effective strategy.

However, it was noted that 50% of the studies considered key aspects such as training, staff involvement, promotion of a safety culture and implementation of surveillance processes to achieve a reduction in nosocomial disease rates. On the other hand, the knowledge that this reduction depends on the implementation of preventive measures makes the internal audit in services and institutions important, as it requires a continuous evaluation to define the measures and the implementation of the policies necessary for their dissemination and maintenance.

These findings highlight the need for further research to determine the most effective educational interventions to prevent the development of healthcare associated infections (HAIs).

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of views and not that of the institution to which they belong.

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Diagnóstico de la enfermedad de Wilson y sus fenotipos usando inteligencia artificial

Diagnosis of Wilson disease and its phenotypes by using artificial intelligence

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Resumen

La EW es causada por las variantes de ATP7B que alteran el eflujo de cobre y provocan una acumulación excesiva de cobre, principalmente en el hígado y el cerebro. El diagnóstico de la EW se ve dificultado por su evolución clínica variable, su aparición, su morbilidad y el tipo de variante ATP7B. Actualmente se diagnostica mediante una combinación de síntomas/signos clínicos, parámetros aberrantes del metabolismo del cobre (por ejemplo, niveles séricos bajos de ceruloplasmina y concentraciones elevadas de cobre urinario y hepático) y cuando están disponibles, a través de pruebas genéticas de mutaciones ATP7B. Dado que el diagnóstico y el tratamiento precoces son clave para obtener resultados favorables, es fundamental identificar a los sujetos antes de la aparición de manifestaciones clínicas manifiestamente perjudiciales. Con este fin, tratamos de mejorar el diagnóstico de la EW mediante algoritmos de redes neuronales artificiales (parte de la inteligencia artificial) integrando los parámetros clínicos y moleculares disponibles. Sorprendentemente, el diagnóstico de la EW se basó en los niveles plasmáticos de glutamato, asparagina, taurina y el cociente de Fischer. Dado que estos aminoácidos están relacionados con los ciclos urea-Krebs, nuestro estudio no sólo subraya el papel central de las mitocondrias hepáticas en la patología de la EW, sino también que la mayoría de los pacientes con EW presentan una disfunción hepática subyacente. Nuestro estudio aporta pruebas novedosas de que la inteligencia artificial utilizada para el análisis integrado de la EW puede dar lugar a un diagnóstico más precoz y a tratamientos mecánicamente relevantes para los pacientes con EW.

Abstract

WD is caused by ATP7B variants disrupting copper efflux resulting in excessive copper accumulation mainly in liver and brain. The diagnosis of WD is challenged by its variable clinical course, onset, morbidity, and ATP7B variant type. Currently it is diagnosed by a combination of clinical symptoms/signs, aberrant copper metabolism parameters (e.g., low ceruloplasmin serum levels and high urinary and hepatic copper concentrations), and genetic evidence of ATP7B mutations when available. As early diagnosis and treatment are key to favorable outcomes, it is critical to identify subjects before the onset of overtly detrimental clinical manifestations. To this end, we sought to improve WD diagnosis using artificial neural network algorithms (part of artificial intelligence) by integrating available clinical and molecular parameters. Surprisingly, WD diagnosis was based on plasma levels of glutamate, asparagine, taurine, and Fischer's ratio. As these amino acids are linked to the urea–Krebs' cycles, our study not only underscores the central role of hepatic mitochondria in WD pathology but also that most WD patients have underlying hepatic dysfunction. Our study provides novel evidence that artificial intelligence utilized for integrated analysis for WD may result in earlier diagnosis and mechanistically relevant treatments for patients with WD.

Introducción

La enfermedad de Wilson (OMIM 277900) está causada por variantes homocigotas o heterocigotas compuestas que afectan al gen ATP7B (OMIM 606882) en el cromosoma 13q14 que afectan al gen ATP7B (OMIM 606882) en el cromosoma 13q14. Este gen codifica para un polipéptido que, cuando actúa como dímero, muestra una actividad de la membrana plasmática [1,2]. La proteína tiene varios dominios de membrana, una secuencia consenso ATPasa, un dominio bisagra, un sitio de fosforilación y al menos dos sitios putativos de unión al cobre situados principalmente en el aparato de Golgi. Al funcionar como monómero, exporta cobre fuera de las células, garantizando el eflujo de cobre hepático a la bilis. Se han caracterizado variantes de empalme transcripcional que codifican diferentes isoformas con distintas localizaciones celulares.

El diagnóstico de la EW se complica por dos factores: el tipo de variante ATP7B y la evolución clínica de la enfermedad. La mayoría de las variantes del gen ATP7B observadas en pacientes incluyen mutaciones nonsense y frameshift junto con las deleciones, pero muy pocas proteínas tipo ATP7B truncadas o modificadas, conservan parte de su actividad nativa. Esto podría constituir la razón principal que subyace a los intentos no concluyentes de correlacionar el genotipo con el fenotipo [3,4] cuando se incluyen los parámetros del cobre [5].

La EW se presenta con una variable de curso clínico. Por ejemplo, los adultos jóvenes manifiestan con más frecuencia los primeros síntomas de la EW [6,7], pero algunos pacientes presentan un inicio tardío de la enfermedad mientras que otros, pueda que no muestren signos evidentes de toxicidad por cobre. Además, la EW suele clasificarse en tres fenotipos: *i*) principalmente hepático (40%); *ii*) neurológico (40%) y *iii*) psiquiátrico o asintomático (20%). Sin embargo, esta clasificación no se ajusta exactamente a los pacientes que presentan EW, ya que los signos neurológicos (por ejemplo, temblor, ataxia, distonía y parkinsonismo) a menudo se observan a menudo de forma concomitante con defectos metabólicos hepáticos [6-10].

Además, los signos neurológicos suelen presentarse más tarde que los asociados a la patología hepática [7,9-11]. Estas dificultades a la hora de reconocer los signos de la EW pueden dificultar la capacidad de los clínicos para realizar un diagnóstico preciso, lo que repercute en la administración de tratamientos personalizados que pueden minimizar la progresión de la enfermedad.

Teniendo en cuenta los retos anteriores, el objetivo de este estudio fue aplicar la inteligencia artificial para ayudar en el proceso de diagnóstico de la EW y sus manifestaciones hepáticas o neurológicas. En este sentido, una red neuronal es una simulación de un cerebro biológico (también conocida como red neuronal artificial o RNA) y una rama de la inteligencia artificial. La RNA se "entrena" primero haciéndola procesar varios patrones de entrada y mostrando qué salida resulta de cada patrón de entrada. Una vez entrenada, la RNA puede reconocer similitudes cuando se le presenta un nuevo patrón de entrada, el resultado es un patrón de salida predicho. De este modo, la RNA detecta señales de alerta temprana provenientes de transiciones críticas definidas como transiciones de estado repentinas y a gran escala que ocurren en sistemas complejos [12,13].

En el caso de la EW, se puede especular que la RNA podría contribuir tanto al diagnóstico precoz de la enfermedad como a la caracterización y predicción de los fenotipos de la enfermedad. En este caso, se utilizará la amplitud de los resultados clínicos y moleculares para detectar similitudes de entrada, permitiendo así que la RNA construya un modelo predictivo para los fenotipos de la EW considerando el diagnóstico de la EW y sus fenotipos como puntos críticos de transición [12,14-19]. Esto puede lograrse incluso con una variabilidad entre sujetos relativamente mayor, como la observada en humanos en comparación con los modelos EW en animales isogénicos/clónicos mantenidos en condiciones controladas y rigurosas.

Métodos

Muestras biológicas

Los datos demográficos y clínicos de los pacientes (edad, sexo e IMC; diagnóstico de EW y subclasificación en hepática, neurológica o asintomática [5]) se recogieron en un único centro, el Segundo Departamento de Neurología del Instituto de Psiquiatría y Neurología de Varsovia, Polonia. Todos los pacientes fueron reclutados cuando estaban en pretratamiento (es decir, no recibían ningún tratamiento contra el cobre). Todos los pacientes fueron diagnosticados con EW tomando como base los criterios de Leipzig, incluyendo niveles bajos de ceruloplasmina, aumento de los niveles de cobre

hepático y urinario en 24 h, presencia de anillos de Kayser-Fleischer, presencia de síntomas neurológicos, anemia hemolítica Coombs-negativa, y eventuales resultados de pruebas genéticas si estaban disponibles, tal y como se había descrito previamente [20,21]. Otras pruebas hepáticas básicas de laboratorio (por ejemplo, la bilirrubina total) se realizaron en el laboratorio del hospital utilizando métodos estándar. Se obtuvieron muestras de sujetos sanos de control de la misma comunidad de Polonia. El estudio fue aprobado por el comité local de bioética y todos los pacientes dieron su consentimiento informado por escrito antes de participar siguiendo la Declaración de Helsinki.

El número de copias y las deleciones de ADN mitocondrial (ADNmt) con determinación total en sangre, se realizó siguiendo el protocolo descrito previamente [22]. Cabe destacar que los sujetos incluidos en el presente análisis son los mismos descritos en nuestro anterior estudio de ADNmt [22]. Los metabolitos séricos se determinaron por espectrometría de masas como se ha descrito anteriormente [23,24]. Los metabolitos séricos se normalizaron con respecto a la media de los valores de control y se expresaron como el pliegue de cambio log2 (log2 PC). Los valores perdidos se sustituyeron utilizando el algoritmo de aproximación de características del vecino k-más cercano.

Red neuronal artificial (RNA) para el diagnóstico

El diseño de la red neuronal para el algoritmo SFAM consistió en una red de tres capas: una capa de entrada, con cuatro unidades para los criterios de diagnóstico definidos como control, EW asintomática o EWA, EW hepática o EWH y EW neurológica o EWN; sexo, edad e IMC; 66 unidades para metabolitos relevantes para el metabolismo hepático, 3 unidades para ratios de metabolitos y 2 unidades para datos asociados al ADNmt; una capa oculta, con 11 unidades; y una capa de salida para el diagnóstico de EW. Para la predicción de la EW y sus fenotipos se utilizó el algoritmo SFAM del software NeuNet Pro (CorMac Technologies Inc., Thunder Bay, ON, Canadá). Las variables de capacitación no supervisada incluyeron todas las indicadas anteriormente. Para seleccionar el tamaño del conjunto de capacitación, se realizó un análisis de la curva de aprendizaje [25].

Básicamente, se extrajo una muestra aleatoria relativamente pequeña de los datos para capacitar una RNA y se utilizó este set de capacitación para predecir un conjunto de prueba muestreado aleatoriamente. A continuación, el tamaño de la muestra de capacitación se incrementó de forma iterativa manteniendo el mismo conjunto de pruebas. Mediante el seguimiento del grado en que la precisión predictiva en el conjunto de prueba, aumentaba con el tamaño del conjunto de entrenamiento, se obtuvieron los datos necesarios de capacitación hasta que las diferencias entre las clasificaciones de la red y los diagnósticos clínicos se tornen aceptables (41 muestras de capacitación y 21 de prueba). También se replicó el análisis de la curva de aprendizaje varias veces con diferentes muestras del conjunto de pruebas para reducir aún más la variación en la precisión predictiva. Por último, los patrones de los hechos de entrada asociados a los diagnósticos, se capacitaron con 41 sujetos seleccionados al azar del conjunto 62 con estado clínico conocido. Una vez capacitada la red, se "probaron" los 21 sujetos restantes mediante la RNA capacitada.

A continuación, las clasificaciones de la red neuronal se compararon con los diagnósticos clínicos conocidos para observar si la red era capaz de clasificar el estado de la enfermedad con fiabilidad. Los mismos datos se analizaron con la Extracción Visual de Reglas, que es una versión altamente optimizada del algoritmo C4.5 publicado por Ross Quinlan [26] para generar un árbol de decisión con poda de árbol ajustable. La extracción inductiva de reglas, relacionada con los campos del aprendizaje automático, el descubrimiento de conocimientos, los sistemas expertos y la inteligencia artificial, suele denominarse "clasificación de árboles de decisión". El método depende del concepto de entropía, introducido en el campo de la teoría de la información por el Dr. Shannon hace más de 70 años [27]. Nuestro análisis incluyó una poda del 75% con mínimo 4 sujetos.

Resultados

Un total de 62 sujetos fueron incluidos en el análisis. De ellos, 47 fueron diagnosticados con EW (23 mujeres/24 varones) con manifestaciones hepáticas prevalentes (EWH; n=18; 11 mujeres/7 varones) y neurológicas prevalentes (EWN; n=18; 7 mujeres/11 varones) o eran asintomáticos (EWA; n=11; 5 varones/6 mujeres). La edad media de los 15 sujetos de control sanos (10 mujeres/5 varones) era de 36 ± 9 años (media ± DE), que no difiere con la de los

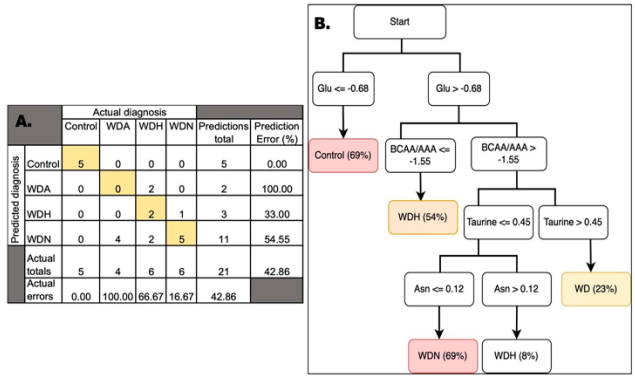
pacientes con EW (34±11años).

Con el fin de aplicar la RNA, se utilizó dos tercios de las muestras seleccionadas aleatoriamente (de las 62) para capacitar la RNA utilizando como datos de entrada el diagnóstico de EW (control sano, EWA, EWH y EWN), la edad, el sexo, el IMC, la bilirrubina total, los niveles de ceruloplasmina, el número de copias y deleciones de ADNmt de la muestra total en sangre y 66 metabolitos séricos relevantes para la fisiología hepática, todos ellos evaluados a través de espectrometría de masas. También se incluyeron las siguientes tres relaciones de metabolitos relevantes: lactato-piruvato, como característica de la disfunción mitocondrial [28]; los niveles de cistina normalizados a la suma de cistina y cisteína, como marcador del estrés oxidativo [29,30] y la relación de Fischer (que es la relación entre los aminoácidos de cadena ramificada (BCAA) y los aminoácidos aromáticos (AAA) [31]), como biomarcador de fibrosis avanzada.

Utilizando un mapa simplificado de teoría de resonancia adaptativa difusa para predecir una clase (en nuestro caso, el diagnóstico de EW), la clasificación RNA identificó a los sujetos con EW frente a los que no la padecían con una precisión del 100% (IC del 95% = 83.89 al 100%) y una sensibilidad y especificidad del 100% (IC del 95%, respectivamente, 79.41% al 100% y 47.82% al 100%). En conjunto, cuando se consideran los diferentes fenotipos, la RNA mostró una precisión del 57.14% (Figura 1A). Los diagnósticos de control y EWN presentaron los menores errores (0% y 16.67%, respectivamente), mientras que los diagnósticos de EWA y EWN presentaron errores del 100% y 66.67%. Los desajustes entre los diagnósticos previstos y los reales se debieron principalmente a la reclasificación del 60% de los sujetos afectados por la enfermedad de Wilson (los cuatro diagnosticados con EWA y dos de los seis diagnosticados con EWH), lo que sugiere la posible existencia de problemas neurológicos subclínicos o no detectados en pacientes diagnosticados con la enfermedad EW bien sea EWA o EWH.

Se analizó la misma configuración a través de un algoritmo de extracción de reglas visuales para determinar qué resultados debían recogerse y en qué orden para llegar a un diagnóstico fiable, qué pacientes necesitaban una segunda opinión respecto a su diagnóstico y, por último, qué combinación de factores era importante para llegar a un diagnóstico (Figura 1B). Nuestros resultados muestran que el diagrama de flujo resultante para determinar el diagnóstico se construyó básicamente sobre valores de nueve aminoácidos y derivados (glutamato, asparagina, taurina, aminoácidos de cadena ramificada y aromáticos; Figura 1B).

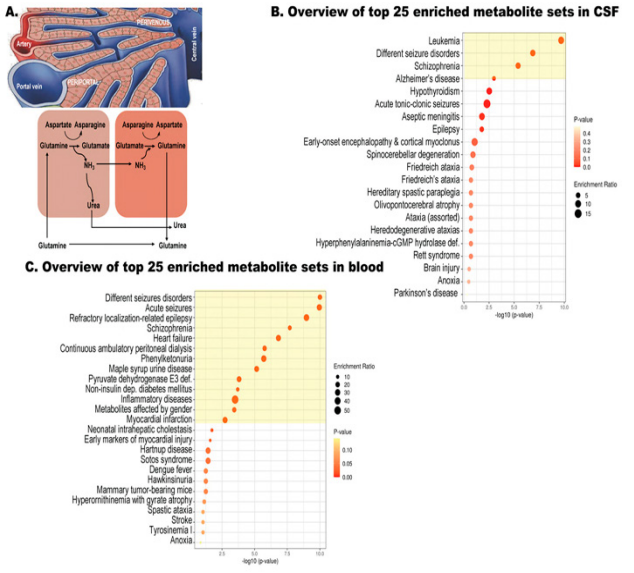
Figura 1. Matriz de confusión y árbol de decisión para el diagnóstico de la EW y sus manifestaciones mediante el uso de redes neuronales artificiales



(A) Las muestras de prueba (n = 21) se "capacitaron" utilizando la RNA obtenida a partir del set de capacitación. Aplicando un mapa simplificado de teoría de resonancia adaptativa difusa, la parte superior de la tabla muestra el diagnóstico real frente al predicho. Los números de las casillas representan el número de sujetos, excepto los errores, que se expresan en porcentajes. Las casillas coloreadas son las que coinciden con los diagnósticos reales y los predichos. **(B)** Árbol de decisión que muestra los principales resultados necesarios para llegar al diagnóstico de la EW y sus fenotipos. Las confidencias diagnósticas (en porcentaje) se indican entre paréntesis. Otros detalles se encuentran en el texto.

El subgrupo de control sano se identificó con un 69% de confianza considerando únicamente los niveles del aminoácido glutamato (log2FC ≤ -0,68; Figura 1B). En pacientes con enfermedad hepática, como los hepatocitos no pueden convertir el amoníaco en urea y glutamina con suficiente rapidez, el nivel de amoníaco en sangre, aumenta. La desviación de la sangre del hígado -como se observa en la hipertensión portal con interferencia en el ciclo intercelular de la glutamina (Figura 2A)- provoca un aumento de los niveles de amoníaco y glutamato. Estos cambios son la probable explicación metabólica subyacente de nuestros hallazgos, lo que indica que los niveles de glutamato podrían ser un factor discriminatorio entre los controles sanos y los pacientes con EW.

Figura 2. Análisis de enriquecimiento de los resultados identificados por RNA y el ciclo intercelular de la glutamina en EW

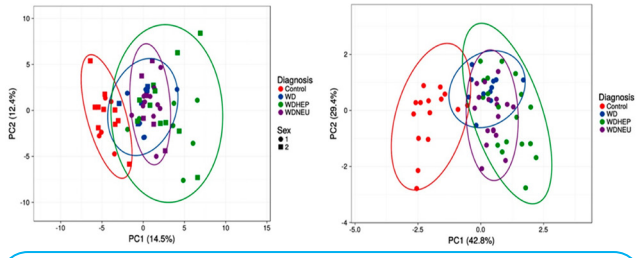


(A) Diagrama que muestra el ciclo intercelular de la glutamina tal como se produce entre las células periportales y las perivenosas que rodean la vena central. La acumulación de cobre induce toxicidad hepática, lo que provoca una disminución de la función del ciclo de la urea que socava la eliminación segura del exceso de amoníaco en forma de urea. El exceso de amoníaco, formado por la acción de la glutaminasa sobre la glutamina (entre otros), se utiliza entonces para generar glutamato a expensas del intermediario del ciclo de Krebs alfa-cetoglutarato, así como aumentos de asparagina a expensas de aspartato. La menor actividad del ciclo de Krebs se traduce en una menor producción de ATP, lo que puede cuestionar la generación de glutamina a partir de glutamato impulsada por el ATP. Los análisis de enriquecimiento se realizaron utilizando los aminoácidos y derivados identificados en la Figura 1B como entrada frente a una base de datos de firmas de enfermedades en LCR **(B)** y sangre **(C).** Aquellos resaltados en amarillo tenían un FDR < 0,05. El análisis se realizó con el software MetaboAnalyst® [33].

Con niveles altos de glutamato, una relación baja de BCAA/AAA (log2FC ≤ -1.55) indica un diagnóstico de EWH con un 54% de confianza. Si los niveles de BCAA/AAA están por encima del umbral, entonces los niveles bajos tanto de taurina (log2FC ≤ 0.45) como de asparagina (log2FC ≤ 0.12) dan lugar a un diagnóstico de NDM con un 69% de confianza (Figura 1B). La combinación de una proporción elevada de glutamato y BCAA/AAA con niveles de taurina por encima del umbral da lugar a un diagnóstico de EW con una confianza del 23% (Figura 1B).

El análisis de enriquecimiento realizado con los nueve aminoácidos y derivados implicados en el diagnóstico de la EW (de la Figura 1B) frente a una base de datos de firmas de enfermedades en líquido cefalorraquídeo humano (Figura 2B) y sangre (Figura 2C) indicó un solapamiento significativo con manifestaciones asociadas a la EW. Entre ellas, se identificaron convulsiones, ataxia, inflamación, trastornos aminoacídicos o metabólicos (solapamiento con diabetes, Hartnup y tirosinemia), trastornos sistémicos (solapamiento con ataxia de Friedreich), deterioro cognitivo [38] y colestasis [39]. Por último, el análisis de componentes principales realizado con todos los resultados frente a los nueve aminoácidos y derivados del árbol de decisión mostró que la separación entre controles sanos y pacientes con EW, es la más eficiente. Por el contrario, tanto los diagnósticos de EWA como de EWN parecen ser subconjuntos del grupo más amplio de EWH, lo que sugiere que todos los pacientes pueden presentar diversos grados de alteración de la función hepática subyacente y potencialmente infradiagnosticada o infravalorada (Figura 3).

Figura 3. Análisis de componentes principales de los cuatro grupos de diagnóstico basados en todos los resultados y los nueve aminoácidos y derivados seleccionados del árbol de decisión



El PCA (utilizando ClustVis 2.0 [40]) se aplicó al conjunto de datos de prueba utilizando todos los resultados como entrada (panel superior; n = 62 puntos). Se aplicó el escalado de varianza unitaria a las filas; se utilizó la descomposición de valor singular con imputación para calcular el análisis de componentes principales (a los paneles superior e inferior). Otras opciones se establecieron de la siguiente manera: no se realizó ninguna transformación de datos y no se realizó ningún colapso de columnas con anotaciones similares; el porcentaje máximo de datos no disponibles permitidos tanto en filas como en columnas se estableció en 99.99; el centrado de filas; la no eliminación de columnas constantes y el escalado de filas, se basó en el escalado de varianza unitaria; el método PCA se calculó utilizando la descomposición de valor singular. Los ejes x e y muestran el componente principal 1 y el componente principal 2, que explican el 14.5% y el 12.4% de la varianza total, respectivamente. Las elipses de predicción poseen una probabilidad de 0,95, y una nueva observación del mismo grupo caerá dentro de la elipse (ambos paneles). El panel inferior se realizó utilizando sólo la relación BCAA/AAA y los niveles de glutamato, asparagina y taurina.

Discusión

En particular, la enfermedad hepática avanzada se asocia a trastornos metabólicos, especialmente en los niveles de aminoácidos, la mayoría de los cuales están directa o indirectamente relacionados con los ciclos de la urea (eliminación de nitrógeno) y de Krebs. Estos resultados también ponen de relieve el papel crítico de las mitocondrias hepáticas en la morbilidad de la EW, como demostraron nuestros propios estudios anteriores [22,32].

Si los niveles de asparagina están por encima del umbral, el diagnóstico es EWH con un 8% de confianza. Aunque la mayoría de los aminoácidos son metabolizados por el hígado, los BCAA son metabolizados exclusivamente por el músculo esquelético. Por lo tanto, en la insuficiencia hepática progresiva y la hepatopatía terminal, como se observa en asociación con la acumulación de cobre, el metabolismo de estos últimos aminoácidos no se ve afectado, mientras que el metabolismo de otros aminoácidos, especialmente los aromáticos, se ve gravemente afectado. Por lo tanto, las concentraciones sanguíneas de BCAA son normales, mientras que las de AAA aumentan, incrementando así la proporción BCAA/AAA. Dado que ambos tipos de aminoácidos se transportan al cerebro a través del mismo portador, el cambio en la relación de concentración aumenta la cantidad de AAA que entra en el cerebro.

Teniendo en cuenta que estos aminoácidos (tirosina y triptófano) son los precursores de aminas biogénicas cruciales, dopamina, noradrenalina y serotonina (5-hidroxitriptamina) y dado que la síntesis de serotonina en el cerebro no contiene un paso generador de flujo, estos cambios en los niveles sanguíneos de aminoácidos aumentan las concentraciones de aminas en el cerebro. Como los niveles de serotonina en el cerebro promueven el sueño, grandes cantidades de triptófano y serotonina podrían explicar los problemas neurológicos y el letargo observados en algunos pacientes afectados por la EW [34]. Estos desequilibrios en los neurotransmisores, junto con los déficits en la eliminación de nitrógeno a través del ciclo de la urea y el desvío de alfa-cetoglutarato del ciclo de Krebs, pueden contribuir aún más al fallo energético y a la toxicidad por amoníaco en el SNC.

Los niveles elevados de taurina parecen proteger de algún modo a los pacientes afectados por la enfermedad de Alzheimer de entrar en una vía que desemboque en el diagnóstico de esta enfermedad. La taurina es un aminoácido libre intracelular abundante que tiene un papel central en el desarrollo del cerebro, y es el segundo neurotransmisor inhibidor más importante después del GABA. También forma conjugados con ácidos biliares y puede mejorar el flujo biliar y aumentar la eliminación del colesterol por el hígado. La taurina, en el contexto del estrés oxidativo inducido por el cobre, también puede desempeñar un papel en la recuperación de intermediarios tóxicos (véase [35] y referencias sucesivas). Curiosamente, la taurina en adultos puede obtenerse de la dieta o de la síntesis a partir de la cisteína cuando la vitamina B6 está presente.

Aunque la deficiencia de vitamina B6 no parece asociarse con frecuencia a las nuevas formulaciones de penicilamina, se ha propuesto que algunos de los efectos secundarios del quelante del cobre D-penicilamina pueden ser el resultado de la interferencia con el metabolismo de la vitamina B6, favoreciendo así problemas neurológicos [36,37]. Dado que los pacientes estudiados no estaban recibiendo ningún tratamiento en el momento de la extracción de sangre, resulta tentador proponer que los aumentos del estrés oxidativo mediados por el cobre pueden reducir los niveles de cisteína, así como los de B6, lo que da lugar a una disminución de la taurina que desencadena algunos de los síntomas neurológicos debido a un desequilibrio entre los neurotransmisores excitatorios e inhibitorios.

El árbol de decisión mostró algunos fenotipos (control, EWH y EWN) que se diagnosticaron con niveles de confianza adecuados, mientras que fue menos útil para EWA. Esto sugiere que, de acuerdo con el análisis ANN, la mayoría de los sujetos afectados por EW podrían en realidad ser EWN o EWH incluso cuando todavía están clínicamente asintomáticos. En particular, cuando los niveles de taurina y asparagina son bajos y los de glutamato altos, el aumento de la proporción de BCAA/AAA

desplaza el diagnóstico de EWH a EWN, lo que sugiere que estos parámetros deberían analizarse en todos los pacientes con EWN para controlar sus manifestaciones clínicas y la posible progresión de los signos y síntomas hepáticos a neurológicos.

Conclusiones

Mediante la evaluación de nueve aminoácidos y derivados, es posible diagnosticar la EW con un nivel de confianza aceptable para aquellos que presentan manifestaciones hepáticas y neurológicas. Sorprendentemente, los resultados que suelen analizarse en la EW, como los niveles de ceruloplasmina y bilirrubina total o los parámetros demográficos y clínicos comunes, como la edad, el sexo o el IMC, no desempeñaron ningún papel en nuestro árbol de decisión. El hallazgo de que nueve aminoácidos reflejan principalmente la función hepática de la ND y la NDH, así como la interacción entre la urea y el ciclo de Krebs, es coherente con el papel de la disfunción mitocondrial tanto en pacientes como en modelos de ratón de la enfermedad [22,32,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57]. Una limitación importante de la cohorte estudiada es la falta de evaluaciones directas (biopsia hepática y análisis histológicos) o indirectas (imágenes hepáticas y cerebrales) de la morbilidad de la enfermedad.

Además, no estamos comparando los casos de EW con otras etiologías de enfermedades hepáticas, y no disponemos de una cohorte prospectiva para evaluar los riesgos longitudinales en el desarrollo de manifestaciones de EW. Algunos de nuestros hallazgos pueden no ser específicos de la EW, sino que podrían estar asociados con la fibrosis hepática y la hipertensión portal en general. Sin embargo, el algoritmo propuesto podría tener un valor incremental si se añade a los parámetros diagnósticos existentes de alteración del metabolismo del cobre (excepto la ceruloplasmina) o a los hallazgos de imágenes hepáticas o cerebrales [58], y podría agilizar el proceso diagnóstico. Podría argumentarse que añadir informes histológicos podría mejorar la precisión del algoritmo basado en RNA. Sin embargo, los diagnósticos y evaluaciones no invasivos de la enfermedad hepática se están convirtiendo en el estándar de atención para la mayoría de las enfermedades hepáticas. Por ello, el acceso a los informes histológicos es menos habitual. Un sistema de puntuación basado en la histología hepática probablemente no ayudará a la práctica clínica actual y futura. Por otra parte, los estudios futuros deberían intentar integrar los sistemas de puntuación validados de la EWH, incluida la puntuación de Leipzig, en los enfoques de RNA para mejorar aún más su precisión clínica.

Además, nuestros hallazgos pueden tener relevancia a la hora de diseñar terapias dirigidas o de optimizar los enfoques dietéticos en el tratamiento de pacientes con EW. Los enfoques dietéticos en la EW deberían tener como objetivo reducir la sobrecarga del ciclo de la urea y, en consecuencia, la disfunción mitocondrial, asegurando al mismo tiempo una ingesta proteica adecuada para minimizar la sarcopenia asociada a la hipertensión portal. Además, el ajuste de la proporción de BCAA/AAA, que se ha estudiado ampliamente como enfoque para el tratamiento de la encefalopatía hepática [59,60,61,62,63,64,65], puede ser especialmente útil en la EW cuando coexisten manifestaciones hepáticas y neurológicas.

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Declaración del Comité de Revisión Institucional

El Comité de Revisión Institucional de la Universidad de California (UC) Davis y el Comité para la Protección de Sujetos Humanos del Estado de California-EEUU aprobaron este estudio (Protocolo No. 818454).

Declaración de consentimiento informado

Se obtuvo el consentimiento informado de todos los sujetos que participaron en el estudio. No se recogieron datos ni muestras hasta que se obtuvo el consentimiento informado por escrito de los pacientes. Se ha obtenido el consentimiento informado por escrito de los pacientes para publicar este artículo.

to the design

Declaración de disponibilidad de datos

Los datos metabolómicos presentados en este estudio se publicaron anteriormente [22,23,24]. En este estudio no se crearon nuevos datos metabolómicos.

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Conflicto de Interés

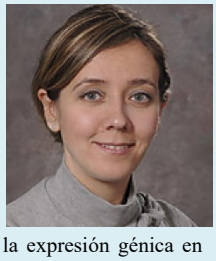
Los financiadores (NIH) no tuvieron ningún papel en el diseño del estudio; en la recogida, análisis o interpretación de los datos; en la redacción del manuscrito o en la decisión de publicar los resultados. Valentina Medici forma parte del Consejo Asesor de Alexion Pharmaceuticals. El resto de los autores declara no tener ningún conflicto de intereses.

Consentimiento de publicación

Los autores leyeron y aprobaron el manuscrito final.

Perfil de Autoría

Valentina Medici



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Anna Czlonkowska

La Prof. Anna Członkowska MD, PhD terminó sus estudios en la Academia de Medicina de Varsovia. Desde 1985, trabaja en el 2º Departamento de Neurología del Instituto de Psiquiatría y Neurología de Varsovia (hasta finales de 2014 como jefa del departamento). Desde hace años también colabora con el Departamento de Farmacología de la Universidad Médica de Varsovia. Sus principales intereses son: el ictus (epidemiología, tratamiento, rehabilitación), la neuroinmunología (esclerosis múltiple, inmunidad local y sistémica en la neurodegeneración) y la enfermedad de Wilson. Ha superado varias becas de investigación en neuroimmunología y neuropatología (Reino Unido, Alemania, EE.UU.) y ha participado en numerosos estudios clínicos sobre accidentes cerebrovasculares. Ha coordinado en Polonia el Programa Nacional de Prevención y Tratamiento del Ictus y la parte neurológica del Programa Nacional de Prevención y Tratamiento de las Enfermedades Cardiovasculares en los años 1997-2008. Es presidenta de la Sección Cerebrovascular de la Sociedad Neurológica Polaca. Es miembro de la junta directiva de la Sociedad de Accidentes Cerebrovasculares de Europa Central y Oriental, de la que fue presidenta durante cuatro años, organizando varios cursos de formación y congresos sobre accidentes cerebrovasculares en esta región. Durante varios años fue miembro del Consejo de la Sociedad Internacional de Accidentes Cerebrovasculares, la Organización Mundial de Accidentes Cerebrovasculares y la Organización Europea de Accidentes Cerebrovasculares.

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Cecilia Giulivi

Profesora adscrita al Departamento de Biociencias Moleculares. Facultad de Veterinaria de la Universidad de California Davis, EEUU. Los campos de estudio por los que es más conocida son: enzimas; genes y bioquímica. Sus principales temas de investigación son la bioquímica, la mitocondria, el óxido nítrico, la óxido nítrico sintasa y el estrés oxidativo. Sus estudios de Bioquímica se centran principalmente en la citocromo c oxidasa, la proteólisis, la fosforilación oxidativa, la intracelular y la superóxido dismutasa. Su trabajo en la fosforilación oxidativa aborda cuestiones como la partícula submitocondrial, que están relacionadas con campos como la prueba de la oxidasa. Su investigación sobre mitocondrias incluye elementos de endocrinología, ataxia, medicina interna y alelo FMR1. Su investigación sobre el óxido nítrico incorpora elementos de citocromo y ATP sintasa. Cecilia R Giulivi ha investigado el estrés oxidativo en varios campos, incluida la degradación de proteínas y el peróxido de hidrógeno. Su trabajo en el campo del óxido nítrico reúne a familias de la ciencia como la partícula submitocondrial, la enzima y el oxígeno. Su estudio sobre Endocrinología integra preocupaciones de otras disciplinas, como Toxicidad, Ataxia y Alelo, FMR1. Su investigación integra cuestiones de especies reactivas del oxígeno, tirosina y degradación de proteínas en su estudio del estrés oxidativo.

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Artículo de Reflexión | *Medicina*

Beneficios de la actividad física en el tratamiento del paciente con falla cardiaca

Benefits of physical activity in the treatment of patients with heart failure

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Acceso Abierto

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Resumen

La falla cardiaca (FC) afecta a más de 23 millones de personas en el mundo. Se ha demostrado que las intervenciones de enfermería mejoran el conocimiento, comportamientos y reingresos hospitalarios. Asimismo, se recomienda realizar alguna actividad física de tipo aeróbico no sólo como medida preventiva, sino que los estudios reportan que se mejora la calidad de vida de los pacientes con enfermedades crónicas y aumenta su bienestar cuando se mantienen activas y realizan sus actividades habituales. Esta reflexión presenta generalidades de la cultura de la actividad física y los beneficios en los pacientes con enfermedades crónicas como la falla cardiaca; está comprobado que el ejercicio físico contribuye a mejorar los síntomas y a aumentar la autoestima. La FC limita la vida de los pacientes por la variedad de síntomas de la enfermedad, pero la evidencia describe la importancia de la prescripción de la actividad física la cual debe hacer parte del tratamiento integral de los pacientes con esta condición.

Abstract

Heart failure (HF) affects more than 23 million people worldwide. Nursing interventions have been shown to improve knowledge, behaviour and hospital readmissions. In addition, aerobic physical activity is not only recommended as a preventive measure, but studies report that it improves the quality of life and well-being of chronically ill patients when they are active and engaged in their usual activities. This reflection presents generalities of the culture of physical activity and the benefits in patients with chronic diseases such as heart failure; it is proven that physical exercise contributes to improve symptoms and increase self-esteem. HF limits the life of patients due to the variety of symptoms of the disease, but the evidence describes the importance of prescribing physical activity which should be part of the integral treatment of patients with this condition.

Introducción

Las enfermedades cardiovasculares (ECV) representan la principal causa de morbimortalidad en el mundo [1], ocasionan 23 millones de muertes cada año y el 1% de la población mayor de 40 años la presenta, con una prevalencia del 10% en adultos de 70 años [2,3]. Por tanto, las tasas de prevalencia representan un desafío para el sistema de salud [4] dado que es una enfermedad cardiovascular crónica que exige un manejo integral del cuidado y de recursos [5].

Según la OMS, existen 26 millones de personas con FC, con prevalencia superior al 10% en mayores de 70 años, con incidencia de 0.2 a 12.4 por 1000 personas y es la causante del 5% de admisiones hospitalarias, además de que su mortalidad general es cercana al 50% a los 4 años [6]. Es por esta razón que la FC genera un alto impacto en la calidad de vida [7] y se estima una prevalencia en el país del 2,3%, una incidencia de 2/1000 entre los 35 y 64 años y 12/1000 entre los 65 a 94 años [8].

La FC, como parte de las ECV, afecta a personas de todas las edades y se proyecta que para el año 2030 más de ocho millones de personas en los EEUU vivirán con esta enfermedad. En la actualidad, los pacientes cuentan con avances en el tratamiento, pero experimentan una alta carga de síntomas, baja capacidad funcional, mala calidad de vida, hospitalizaciones frecuentes y mortalidad temprana [9]. Estas dificultades a la hora de reconocer los signos de la EW pueden dificultar la capacidad de los clínicos para realizar un diagnóstico preciso, lo que repercute en la administración de tratamientos personalizados que pueden minimizar la progresión de la enfermedad.

En América Latina, la insuficiencia cardíaca (FC) ostenta el sombrío estandarte de ser la primordial instigadora de fallecimientos. En el caso específico de Colombia, esta realidad se replica con una prevalencia prominente del 30% [10,11], posicionándose dentro del aciago repertorio de las diez causas más influyentes de morbimortalidad [12]. Tal coyuntura se ve acentuada por la variabilidad de los factores de riesgo, los cuales reverberan en forma disímil a lo largo de las distintas regiones [13]. Resulta, por lo tanto, imperativo que los eruditos de la enfermería dirijan intervenciones con el propósito de catalizar un impacto más enjundioso en la salud de los pacientes, traducido en una optimización palpable de los protocolos terapéuticos [14]. La escala de pruebas revela de manera inequívoca que las intervenciones inciden de modo benéfico en el autogobierno de los pacientes aquejados por la FC [15], siendo oportuno recalcar que las etiologías de internación guardan concomitancia con prácticas de autocuidado carentes de acierto [16].

A través de la aplicación de intervenciones de enfermería, se logra potenciar de manera significativa la administración del cuidado, concomitantemente disminuir las tasas de hospitalización [17] y fomentar de manera inequívoca la adherencia al tratamiento en individuos aquejados por la FC. Surge, por tanto, que la instrucción configura un proceso catalizador para inculcar los saberes y destrezas imperativas [18], materializándose mediante programas de intervención orquestados con acierto por el cuerpo de enfermería [19,20].

El objetivo de este artículo de reflexión es analizar y discutir la relación entre la cultura de la actividad física y los beneficios que puede aportar a pacientes con enfermedades crónicas como la falla cardíaca. A través de la presentación de generalidades sobre la cultura del ejercicio y su impacto en la salud, esta reflexión busca destacar cómo el ejercicio físico puede tener efectos positivos en los pacientes que sufren de esta condición específica. En particular, el artículo se enfocaría en los siguientes aspectos: *i*) contextualización de la cultura de la actividad física; *ii*) falla cardíaca y sus efectos en la calidad de vida; *iii*) beneficios del ejercicio en pacientes con falla cardíaca; *iv*) integración de la actividad física en el tratamiento integral; *v*) desafíos y consideraciones; y *vi*) promoción de cambios culturales.

Falla cardiaca (FC)

La falla cardiaca (FC) representa la imposibilidad del corazón para suplir los requerimientos metabólicos de los tejidos en reposo o durante el ejercicio leve [21]. Este síndrome clínico se manifiesta mediante síntomas y signos característicos de FC, acompañados de pruebas objetivas que indican una alteración estructural o funcional del corazón [21]. Esta alteración, a su vez, conlleva a una disminución en la capacidad de bombeo del corazón, resultando en una insuficiencia para satisfacer las demandas corporales, situación que puede ser precipitada por condiciones como hipertensión o enfermedad coronaria [22]. La denominación alternativa para FC es insuficiencia cardiaca (IC), una afección originada por anormalidades estructurales o funcionales del corazón que comprometen tanto su capacidad de llenado como de expulsión ventricular de sangre [23]. En conjunto,

estas manifestaciones reflejan un deterioro en la función cardiaca con implicaciones clínicas significativas.

La Tabla 1, elaborada con base en las directrices de la Asociación Americana del Corazón (AHA) [24], emerge como un hito destacado al presentar una redefinición innovadora de la clasificación de la falla cardiaca (FC). Esta reestructuración no solo resume de forma concisa las estrategias de manejo integral del paciente, sino que también introduce elementos conceptuales adicionales que se ajustan a su estado de salud particular. Un vistazo a los años recientes revela avances notables en el ámbito farmacológico para la FC con fracción de eyección reducida (HFrEF), logrando un progreso sustancial [25-30] que impacta significativamente en el enfoque terapéutico. En paralelo, se dirige la atención hacia el abordaje de la FC con fracción de eyección conservada (HFpEF) [31], poniendo de relieve la gestión de síntomas a través de diuréticos y la optimización de comorbilidades, incluyendo hipertensión arterial, obesidad, diabetes mellitus y fibrilación auricular[32]. Este enfoque global y detallado subraya el continuo compromiso con la progresión terapéutica, atendiendo a la diversidad de manifestaciones presentes en el espectro de la FC.

Prescripción de la actividad física

La prescripción de la actividad física en el contexto de la falla cardiaca (FC) adquiere una relevancia crucial. La práctica regular de actividad física se erige como un recurso que trasciende la mera recomendación, respaldada por evidencias sólidas [33,34]. Específicamente, en pacientes con FC compensada en estadios funcionales I-III, la integración de actividad física con fines de mejora y sintomatología decreciente, junto con la modulación de la activación neurohormonal, ha sido demostrada como una estrategia segura y efectiva [35]. Con el flujo constante de nuevas investigaciones que redefinen el diagnóstico y los enfoques de atención en el ámbito de la FC, desde el seguimiento hasta la rehabilitación [36-38], así como la configuración del equipo multidisciplinario [39,40], emerge un panorama que trasciende la atención convencional.

La actividad física, más allá de su rol terapéutico, se establece como un escudo protector en la prevención de la FC. El tejido de investigaciones sostiene que niveles elevados de actividad física en sus múltiples manifestaciones –total, de tiempo libre, vigorosa, ocupacional, caminar y andar en bicicleta–, junto con la aptitud cardiorrespiratoria, están correlacionados con un riesgo disminuido de desarrollar la afección [41]. Asimismo, la actividad física de naturaleza aeróbica [42] se erige como un regulador en la esfera de la FC, asociándose con mejoras tanto en la capacidad funcional como en los síntomas.

En consecuencia, la orientación hacia una participación activa en la actividad física se entrelaza con la seguridad y efectividad intrínsecas para los pacientes con FC, según lo preconizado en las directrices de la Asociación Americana del Corazón (AHA) y la Sociedad Europea de Cardiología (SEC) [43]. Esta recomendación va más allá de una mera sugerencia, responde a un paradigma respaldado por la robustez de la investigación y promete un futuro donde la actividad física ocupe un lugar prominente en la lucha contra la FC.

En la vanguardia actual, se perfilan estudios multicéntricos en curso [44] destinados a iluminar los beneficios precisos que la actividad física acarrea para los pacientes aquejados por la falla cardiaca (FC). Paralelamente, investigaciones recientes han escrutado a fondo a pacientes afectados por la FC, evidenciando una merma significativa en sus capacidades funcionales, vínculo que encuentra resonancia en su pronóstico a futuro. Sin embargo, este correlato no se limita meramente a la declinación en las aptitudes funcionales, sino que se extiende a la dimensión del rendimiento físico en pruebas funcionales, un factor intrínseco en la proyección del pronóstico en pacientes con FC [45,46]. Es en este contexto que la disciplina del entrenamiento físico emerge como un catalizador de múltiples mejoras en el panorama de la salud, especialmente en individuos con fracción de eyección ventricular izquierda (FEVI) conservada[47,48]. Así, la esfera investigativa abarca tanto a pacientes con FC y FEVI reducida como conservada, reflejando una visión integral [49,50]. En este mismo tenor, se subraya la relevancia clínica de optimizar la prescripción de ejercicios, un matiz que encuentra un lugar prominente en el espacio de la toma de decisiones médicas [51].

Un enfoque meta-analítico [52] arroja luz sobre la eficacia de diversos tipos de entrenamiento físico en el ámbito de la FC. Estrategias como la rehabilitación con ejercicios, se revelan como agentes de transformación, capaces de repercutir en la función cardíaca [53,54], la capacidad de ejercicio y la calidad de vida vinculada a la salud, al tiempo que ejercen un impacto positivo en la ansiedad y la depresión que a menudo acompañan a los pacientes con FC.

Tabla 1. Nueva clasificación de los tipos de FC según AHA 2022 [55]

Clasificación de Falla Cardiaca	Con fracción de eyección del ventrículo izquierdo (FEVI) reducida (FEVI<40%) FC-FEr), ligeramente reducida (41-49%) (FC-FElr), conservada ³ 50% (FC-FEc). En la definición de FC-FElr e FC-FEc debemos considerar el aumento de presiones ya sea mediante péptidos, medición no invasiva o invasiva por hemodinámica. Se incluye además el concepto de FEVI mejorada para referirse a aquellos pacientes con FC-FEr previa que ahora tienen una FEVI > 40%.
Etapas de la FC	Las etapas de la FC fueron revisadas para enfatizar las nuevas terminologías de "**en riesgo"** de FC para el estadio A y **"pre-FC"** [56]. En el estadio A (paciente con factores de riesgo cardiovascular) es clave prevenir el desarrollo de FC, con terapias como los inhibidores del cotransportador de sodio-glucosa tipo 2 (iSGLT2) en todo paciente con diabetes y riesgo cardiovascular. En el estadio B (pacientes con cardiopatía estructural sin clínica) el uso de inhibidores de la enzima de conversión de la angiotensina (IECA) y betabloqueantes tienen un nivel de evidencia I.
Terapia Médica	En FC-FEr, la terapia médica incluye 4 clases de tratamiento: iSGLT2, betabloqueantes, antagonistas mineralocorticoide e inhibidores de la neprilisina y del receptor de la angiotensina (ARNI). El sacubitrilo/valsartán tiene indicación I-A, siendo la primera opción de tratamiento por delante del IECA, dejando el IECA solo en caso de no existir posibilidad de tratamiento con ARNI. Además, el ARNI es coste efectivo respecto al IECA por la reducción en eventos cardiovasculares. Con una indicación IIb se recogen nuevas terapias como vericiguat, ácidos grasos poliinsaturados y quelantes de potasio en pacientes con hiperpotasemia e FC.
Recomendaciones en pacientes con FC reducida	En pacientes con FC-FElr, los iSGLT2 presentan un nivel de recomendación IIa tras EMPEROR-Preserved y el resto de los tratamientos usados en pacientes con FEVI < 40%, (IECA-ARA-ARNI; antagonistas mineralcorticoide y betabloqueantes) reducen su evidencia a IIb. En pacientes con FC-FEc, los iSGLT2 tienen la misma indicación IIa siguiendo los datos del subestudio de EMPEROR-P en aquellos pacientes con FEVI > 50%, y mineralocorticoide, ARNI o ARA-II tienen indicación IIb. Los betabloqueantes no tienen indicación en este grupo de pacientes. La cardiopatía amiloide tiene nuevas recomendaciones para el tratamiento que incluye detección de cadenas ligeras monoclonales en suero y orina, gammagrafía ósea, análisis genético, terapia estabilizadora de tetrámeros y anticoagulación. Pacientes con FEVI recuperada deben de mantener el tratamiento de FC-FEr. Pacientes con FC avanzada que deseen prolongar la supervivencia debe derivarse a un equipo especializado en FC avanzada, los cuales evalúan la idoneidad para terapias avanzadas de FC y usos paliativos, incluidos inotrópicos. Se proporcionan recomendaciones para las diferentes comorbilidades en pacientes con deficiencia de hierro, anemia, HTA, trastornos del sueño, DM tipo 2, fibrilación auricular, enfermedad de las arterias coronarias y neoplasia.

En la búsqueda de la optimización, el ejercicio aeróbico y el entrenamiento surgen como pilares de la reconfiguración, delineando mejoras concretas en parámetros que atañen a la función física [57-60] del paciente. Este panorama convergente pone de manifiesto la expansión del horizonte terapéutico, donde la actividad física deviene en un componente central, con el potencial de remodelar significativamente el curso de la FC.

Conclusión

En el cierre de esta exploración, se destaca inequívocamente la relevancia que las investigaciones han conferido a la prescripción de actividad física en pacientes con condiciones crónicas, en particular la falla cardiaca. El enraizamiento de este principio en el cuidado integral del paciente amplifica el llamado a la acción para el equipo multidisciplinario, quienes asumen el rol de cimentar esta dimensión en el núcleo mismo de la gestión asistencial. Dentro de este marco, los profesionales de enfermería se alzan como agentes clave para instaurar intervenciones oportunas y holísticas, trascendiendo las fronteras de la enfermedad y abrazando la promoción y mantenimiento de la salud en su máxima expresión.

Si bien la participación en actividades aeróbicas constituye un pilar esencial en esta estrategia, se delinea un espacio para la adaptación en casos particulares. La fracción de eyección ventricular izquierda (FEVI), actuando como medida singular, se erige como un recurso pertinente para alcanzar beneficios sustanciales (p=<0.00001) [61] en ausencia de efectos adversos en los parámetros del ventrículo izquierdo. En este sentido, se erige la premisa de individualizar la prescripción de actividad física en pacientes con falla cardiaca, sopesando con prudencia las limitaciones y potencialidades de cada individuo.

En este contexto, la presente reflexión cobra una dimensión más sólida y convincente. La premisa de que la prescripción de actividad física trasciende la retórica se afianza, encomendando al equipo multidisciplinario la responsabilidad de incorporar

este precepto en la médula misma de la atención al paciente. Los profesionales de enfermería, encarnando el alma de esta atención, asumen el papel de arquitectos de intervenciones oportunas y holísticas, donde la actividad física no solo se presenta como un complemento terapéutico, sino como un cimiento para la salud y el bienestar a largo plazo.

En esta sinfonía terapéutica, se observa que la actividad física, en su forma aeróbica o a través de la medición de la fracción de eyección ventricular izquierda (FEVI), trasciende su dimensión meramente física y se adentra en el tejido mismo de la recuperación. No obstante, la individualización de esta prescripción emerge como un mandato, un recordatorio constante de la singularidad de cada paciente y la necesidad de adaptar la estrategia a sus circunstancias.

En la antesala de esta conclusión, se abre la puerta hacia una realidad inexplorada. La llamada a futuros estudios de intervención resuena con mayor potencia, insinuando un horizonte que brilla con el fulgor de posibilidades aún no descubiertas. En este empeño colectivo, la amalgama entre la investigación y la atención asistencial emerge como el crisol donde se forjarán las soluciones y estrategias que guiarán la actividad física en la falla cardíaca hacia su ápice terapéutico. En última instancia, se traza un sendero de transformación, donde la cultura de la actividad física se fusiona con la atención médica, consolidando una alianza destinada a moldear un futuro donde el ejercicio físico se consolide como una piedra angular en la lucha contra la falla cardíaca y otras enfermedades crónicas.

Consentimiento de publicación

Las autoras leyeron y aprobaron el manuscrito final.

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Analysis of nursing programme completion rates in a southwestern Colombian university

Análisis de las tasas de culminación del programa de enfermería en una universidad del suroccidente colombiano

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Abstract

The aim of this research was to determine the graduation rate of a nursing programme and to explore the factors that contribute to or hinder the successful completion of the programme. The research adopted a descriptive approach, using a sample of students enrolled in and graduating from a nursing programme at a university in the southwestern region of Colombia, from 2012 to 2021. Data for the study were obtained from the university's academic records, meticulously organised and analysed using Microsoft Excel® spreadsheets. The analytical process involved extensive descriptive statistical analysis, including frequency tables, indices and proportions. The ethical considerations of the study were duly addressed, with formal approval from the Ethics Committee of the Faculty of Health, as documented in Law No. 05 of 22 April 2022. The cumulative graduation rate for the nursing programme for the period 2017 to 2021 was 37.9%. In addition, the study provided insights into the graduation rates for specific cohorts, with the following findings: for the cohort from 2012 to 2017, the rate was 18.2%; for the cohort from 2013 to 2018, the rate reached 32.3%; the cohort from 2014 to 2019 recorded a rate of 37.1%; similarly, the cohort from 2015 to 2020 recorded a rate of 40.5%, while the most recent cohort from 2016 to 2021 achieved a rate of 43.3%. Further examination of the data revealed that certain academic and socio-economic-personal factors significantly influenced successful completion of the programme. These included a strong affinity with the programme's "vocation of service to humanity" and crucial family support in a spiritual context. Looking at the cumulative and cohort-specific completion rates, it became clear that the attrition rate, which includes students who either partially or completely withdrew from the programme during their studies, was over 50%.

Resumen

El objetivo de esta investigación fue determinar la tasa de graduación de un programa de enfermería y explorar los factores que contribuyen o dificultan la finalización exitosa del programa. La investigación adoptó un enfoque descriptivo, utilizando una muestra de estudiantes matriculados y graduados de un programa de enfermería en una universidad de la región suroccidental de Colombia, entre 2012 y 2021. Los datos para el estudio se obtuvieron de los registros académicos de la universidad, se organizaron meticulosamente y se analizaron utilizando hojas de cálculo de Microsoft Excel®. El proceso analítico implicó un extenso análisis estadístico descriptivo, incluyendo tablas de frecuencia, índices y proporciones. Las consideraciones éticas del estudio fueron debidamente atendidas, con la aprobación formal del Comité de Ética de la Facultad de Salud, conforme documentado en el acta No. 05 del 22 de abril de 2022. La tasa de graduación acumulada para el programa de enfermería para el período 2017 a 2021 fue del 37.9%. Además, el estudio proporcionó información sobre las tasas de graduación para cohortes específicas, con los siguientes hallazgos: para la cohorte de 2012 a 2017, la tasa fue del 18.2%; para la cohorte de 2013 a 2018, la tasa alcanzó el 32.3%; la cohorte de 2014 a 2019 registró una tasa del 37.1%; de manera similar, la cohorte de 2015 a 2020 registró una tasa del 40.5%, mientras que la cohorte más reciente de 2016 a 2021 alcanzó una tasa del 43.3%. Un examen más detallado de los datos reveló que ciertos factores académicos y socioeconómicos-personales influyeron significativamente en la finalización con éxito del programa. Entre ellos, una fuerte afinidad con la "vocación de servicio a la humanidad" del programa y un apoyo familiar crucial en un contexto espiritual. Si se observan los índices de finalización acumulados y específicos de cada cohorte, queda claro que el índice de abandono, que incluye a los estudiantes que abandonaron parcial o totalmente el programa durante sus estudios, fue superior al 50%.

Introduction

Currently, there is a chronic shortage of nursing staff, which, combined with the progressive ageing of the population, is a time bomb for health systems. It is therefore necessary to redistribute financial resources not only to the social services for the elderly, but also to the higher education institutions that train qualified personnel, in order to maintain and increase the graduation rate in nursing schools [1].

On the other hand, the economic, family and emotional costs of dropping out and/or prolonging one's studies lead to costs that are not visible to society, and although the graduation rate is an indicator of interest, few publications report this data; OECD (Organisation for Economic Co-operation and Development) member countries report values between 60 and 70% [2]. It is important for nursing to study this phenomenon because it provides a clear idea of the effectiveness of government, industry and educational interventions to recruit, retain and avoid attrition, as well as to guarantee the time students need to complete their degree [1].

Two methods have been described in the literature to operationalise the graduation rate: the first, the simplest, is to divide the number of graduates by the number of students enrolled in a given year, multiplied by 100; this value is understood as the percentage of students who graduate from the institution regardless of the time. The other method is more complex and is perhaps the most recommended, since it takes into account the time required for the student to graduate according to the academic programme chosen. The latter starts with a specific cohort and follows it over time until the moment of graduation, taking into account the prescribed or legal duration of the programme for the university (the calculation method used in this study). Taking into account both methods of measurement, the percentages reported in the literature do not have the same meaning; in addition to the limited availability of data on enrolled students and graduates in universities, the process of researching this phenomenon and disseminating knowledge is hampered by aspects of content and form [1-8].

In view of the above, the present study seeks to determine the graduation rate and the aspects that facilitated or hindered the completion of the nursing programme within 5 years from the first enrolment in a university in the southwest of Colombia, cohorts enrolled between 2012 and 2016.

Methods

Research design

This research is quantitative, cross-sectional and descriptive in nature. The focus of the study is on nursing education in the context of South West Colombia. The sample for this research was carefully selected to include both current students and graduates of a nursing programme. The time frame covers the years 2012 to 2021, providing a comprehensive view of the evolution of nursing education.

Participants and criteria

Participation in the study was based on a set of strict inclusion criteria. Specifically, individuals were considered eligible if they were financially and academically enrolled in the first semester of their nursing program between 2012 and 2016, thus providing a lens into the formative stages of nursing education. In addition, the sample included individuals who successfully completed their nursing program between 2017 and 2021, effectively engaging in a higher education journey that began five years earlier.

Exclusion parameters

Participants from other nursing programs in different institutions during the period 2012-2021 were intentionally excluded, ensuring a focused and coherent lens on the specific nursing program under study. This measured approach was taken to emphasise the uniqueness of the scope of the study and to ensure the applicability of the findings within the context of the targeted nursing program in southwest Colombia.

Study variables

The focal points of the study encompassed a comprehensive set of variables, each meticulously framed to capture the nuanced landscape of nursing education dynamics.

Total graduation rate (2017-2021)

This key metric quantified the success trajectory of the nursing programme over a specified five-year period, from 2017 to 2021. It was a numeric articulation, expressed as a percentage, that captured the ratio of the total number of students who began

their nursing education five years earlier (from 2017 to 2021) to the total number of graduates from the same nursing program during that period. This numerical articulation was then multiplied by 100 to provide a comprehensive assessment of the programme's overall graduation effectiveness within this time window.

Cohort-specific graduation rate (2012-2016)

Within the broader tapestry of the study, a particular lens was focused on the graduation rates per academic semester within the 2012-2016 cohort. This granular perspective involved a precise numerical articulation, expressed as a percentage, that skilfully captured the interplay between the number of students who were financially and academically engaged in the first semester of the nursing programme for each academic semester, and the corresponding number of students who successfully completed their higher education journey five years earlier, per academic semester. This numerical composition was then multiplied by 100, resulting in a nuanced and cohort-specific representation of the graduation dynamics of the nursing programme.

The calibrated delineation of these variables ensured a multidimensional and comprehensive exploration of the effectiveness and evolution of the nursing programme, painting a complex picture of its impact on student progression and academic achievement.

Data collection

The information was obtained from the university's academic records and organised into a Microsoft Office Excel® spreadsheet that allowed students to be identified by name and identification number for the period of initial enrolment in the nursing programme and the period of graduation from the programme. This facilitated the extraction of the number of students enrolled and graduated to generate the number of graduates by cohort and for the programme as a whole. In order to identify the aspects that facilitated or hindered the completion of the programme within 5 years from the initial enrolment, a self-administered questionnaire (Google form) was developed and sent to the graduates through institutional and/or personal emails registered by the students in their degree application, social networks and the WhatsApp group of graduates of the nursing programme.

Data analysis

The intricacies of data analysis unfolded as a meticulous orchestration, stemming from an urgent need to encapsulate the essence of the study's constructs. With empirical indicators evading identification, the researchers meticulously crafted a bespoke form, a manifestation of their exhaustive literature review. This dynamic quest navigated a maze of scholarly discourse, yielding two robust clusters that delineate the academic and the socio-economic-personal realms. This instrument, entitled "Characterisation of Aspects Influencing Higher Education Programme Completion", consisted of 17 closed-ended items cleverly positioned within a Likert scale framework. The gradation of responses ranged from '1', indicating challenges to timely programme completion, to '5', symbolising the catalytic role in facilitating programme completion within the required five-year period. To steer the analysis through this multifaceted terrain, the study plan embraced a descriptive statistical framework, manifested through the synthesis of frequency tables, indices and proportions. This approach harnessed the power of quantification to convey the essence of participants' responses, an approach reinforced by the formidable tabulation and control capabilities of Microsoft Office Excel® spreadsheets.

Institutional review board statement

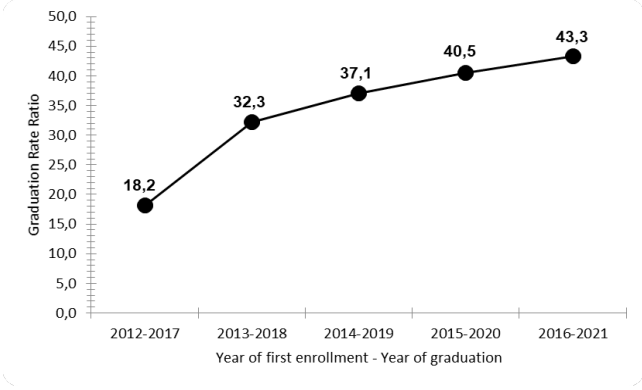
The research is considered low-risk because no psycho-physiological variables of the participants were manipulated; however, the confidentiality and privacy of the information (identification data of the students) was maintained through exclusive access to the database of the principal investigators by means of a password. The authors also undertook to guarantee the anonymity of the information. The study was approved by the Ethics Committee of the Faculty of Health in accordance with Law No. 05 of 22 April 2022. This manuscript has been prepared according to the STROBE checklist.

Results

Students who completed their studies were on average 26.3 years old (SD= +/- 4.6), one sixth were male and 25.7% lived in rural areas. Only 288 students completed their studies in the five-year framework (2017-2021), while the total number of students enrolled in the 2016-2020 period was 760, resulting in an overall programme completion rate of 37.9%. On the other hand, Figure 1 shows the upward trend of the graduation rate by cohort between 2012 and 2016, which ranged from 18.2% to 43.3%. This

represents a progressive increase from 2.8% to 5.1% in the 5 cohorts analysed.

Figure 1. Graduation rate by cohort of students enrolled in nursing programmes in 2012 - 2016

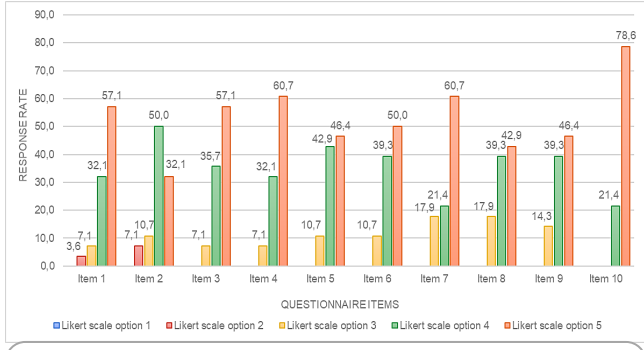


The survey was sent to 288 students who had completed the programme by the deadline, and only 28 responded (response rate 9.72%). The majority of graduates who participated were women (82.1%), with an average age of 28 years (SD: +/- 5 years), 60.7% working in clinical care, 25% in community roles (health promotion and disease prevention), and the remainder in teaching, health and safety, and school roles. Finally, the majority lived in the south-west of Colombia, with only two participants living and working abroad.

In terms of the academic aspects that made it easier to complete the programme within the time limit set, graduates mentioned: the call to serve humanity (78.6%), the interaction with the teacher in the labs, simulated hospital or clinical practice (60.7%) and the interpersonal relationships with classmates throughout the curriculum (60.7%). However, two aspects stood out as being close to the bottom of the list of elements that hindered the successful completion of the programme: interaction with the teacher in class (10.7%) and the integration of the knowledge acquired in class with the reality of the patient, his family and the socio-cultural-economic environment of the country (17.8%) (see Figure 2).

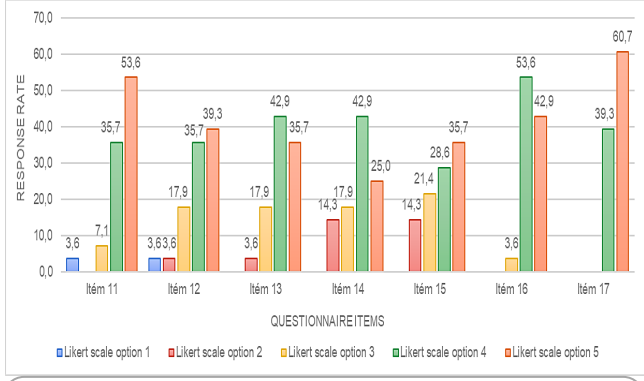
On the other hand, the socio-economic-personal aspects that facilitated the completion of the programme in the five years were: spiritual (60.7%) and economic (53.6%) family support (42.9%). However, one aspect that stood out because it was rated among the options that hindered the completion of the programme was: the lack of flexibility in the enrolment schedules of the courses of the study plan (25.1%). The item with the greatest variability in response options was number 15, which asks about extracurricular leisure, sports, health and cultural activities during the study period (see Figure 3).

Figure 2. Academic aspects that, according to graduates, determine the successful completion of the nursing programme are



Item1= Interaction with the teacher in class; item 2= The integration of the knowledge learned in class to the reality of the patient, his family and the social-cultural-economic environment of the country; item3= The development of learning strategies (e.g., study groups, creating summaries, organizing fixed study schedules, etc.; item4= My interpersonal relationships with my peers throughout the curriculum; item5= My academic performance throughout the curriculum; item6= My adjustment to college life; item7= Interaction with the teacher in laboratories, simulated hospital or clinical practice; item8= Pedagogical strategies in the classroom; item9= The thematic contents of the courses in the curriculum; item10= My identification with the "vocation of service to humanity" that the discipline of nursing requires.

Figure 3. Socio-economic-personal aspects that, according to the graduates, determine the success of having completed the Nursing Programme



Item11= Family financial support (e.g., tuition, living expenses, study materials, vaccinations, transportation, food, etc.); item 12= Flexibility in enrollment schedules for courses in the curriculum; item13= Family support in the emotional and mental health aspects (e.g., accompaniment, advice, encouragement, affection); item14= The different methods of payment of financial tuition at the university; item15= Extracurricular activities (recreation, sports, health days, culture and university welfare);item16= Family social support (e.g., support from extended family, friends, boyfriends, girlfriends, neighbors); item17= Family support in spiritual matters (e.g., principles, values, beliefs, religion).

Discussion

This study found that nursing students complete their higher education process at the end of the second and beginning of the third decade of life, findings similar to those reported in other studies of nursing and other health professions such as medicine [5-8]. Nursing continues to be a predominantly female profession [1], but there is evidence of a gradual increase in male participation, particularly in programmes that focus on graduate networking [5,6] or are virtual and accelerated [7]. Few studies report on the origin of students, with only one mentioning that a small proportion (7.1%) live in rural areas [5].

On the other hand, the graduation rate in this study was 37.9%, a result similar to that reported by an African university in 2017 (26.8%) [2]. In contrast, studies developed in the United States report rates ranging from 49.6% (1.5) to 95% (6.8), which is in line with the results reported for professions such as medicine, which exceed 83% [7]. Similarly, the graduation rate per cohort is rarely socialised in research, the few that do present considerable differences, in an African university, this rate moved in a range from 7.3% (2003) to 27.5% (2006), the Faculty of Health being the one that presented rates above 35% in most cases [2], a percentage close to that found in this research, which ranged from 18.2% (2012) to 43.3% (2016). On the other hand, a study developed in the Netherlands reported that medical schools had a rate that ranged from 77-91%, being higher for those whose curricula emphasised active learning [4].

With regard to the academic factors mentioned by the graduates in this study that determined their successful completion, several are also recognised in the literature, among the most frequently mentioned are the pedagogical and assessment practices used by teachers [9,10], the academic performance of students throughout the curriculum [11-13] and integration into university life [10,14].

Two aspects stand out as receiving low scores: interaction with the teacher in class and the ability to integrate knowledge with reality. At the moment, there is no evidence to contrast these results from a quantitative point of view, but it is important to reflect on what happens in the classroom that causes the student to rate this item with a score of 2 and 3 (10.7%), what is the impact of the number of students in the class, the amount of topics to be covered in a reduced period of time, the methodological strategies for transmitting knowledge, the quality and quantity of time the student has to prepare for theoretical classes and their subsequent study, etc.? All of these questions require a qualitative approach to the phenomenon, which makes it possible to analyse the reasons and transform the curricula.

However, there are four aspects in the literature that are associated with increasing the completion rate. The first is to offer more scholarships and student grants for the payment of tuition fees or financial support [10,11], which in this study had a low qualification (3.6%), i.e. their existence contributed very little to the successful completion of the programme. The second is to improve the distribution of the academic load in the curriculum [9], an aspect that was not evaluated in the present study, but which invites us to explore a more balanced organisation of the courses in the curricula that helps the student to have a more complete life.

The third aspect is the student's identification with the chosen career. In this research, this characteristic received the highest rating of all the elements evaluated (78.6%), which is consistent with what is reported in the literature [9]. A situation that should lead us to reconsider the processes of guidance in the choice of career and in the processes of admission to nursing programmes, in order to channel people with an affinity for the human sciences. Finally, although not evaluated in this study, the reduction of class sizes, personalised teaching and tutoring by teachers and/or peers is a constant finding in studies, highlighting the importance of teacher-student interaction in spaces outside the classroom [9,10,15-17].

On the other hand, in the present study, the student's economic situation was fundamental to the student's persistence and successful completion of the study plan. Several studies mention that this may be due to family support, belonging to an upper-middle socioeconomic class with parents who have a university degree, or having a job that allows the student to earn a salary above the country's per capita income are factors that contribute to successful completion of the study plan [9,11,18,19]. This last situation - working in the health sector while studying for a bachelor's degree in health - is highlighted by some authors as an element of motivation and empowerment to promote progress and completion of the bachelor's degree. However, numerous studies have linked employment status to attrition [9, 20].

The main limitation of this study was the limited access to information on the socio-demographic, work, family and academic characteristics of students and graduates, which made it difficult to carry out a more complex analysis to identify predictors of the graduation rate. It is worth exploring successful strategies to increase on-time completion rates in other parts of the world, with similar socio-demographic, cultural and economic characteristics to those in this study, in order to replicate them and measure their impact.

Conclusion

The overall graduation rate for the programme was 37.9%, while the graduation rate per cohort ranged from 18.2% to 43.3%; these values indicate that there is an attrition rate (students who continue in the study period, partially or completely drop out of the programme) of more than 50%. However, academic (e.g., interaction with the teacher in theory and practice), social (e.g., interpersonal interactions with fellow students), family (e.g., emotional and spiritual family support), economic (e.g., modalities of payment of financial tuition) and institutional (e.g., thematic content of the courses of the curriculum) aspects influence the successful completion of the study programme within the period set by the university, according to the graduates of the nursing programme.

These data take on greater significance when it is understood that the programme is a day programme, that most of the students study under educational credits and that the target population is people who are working and/or have as a previous level of training the qualification of auxiliary nurse, which means that they work 48 hours a week, in shifts of 8 hours, making it more complex to combine work, study and family life, or else they have to work one semester to study the next, taking the student more time than planned to complete their higher education. It is imperative that data on successful completion of the chosen nursing programme be published on university websites and requested by the Ministries of Higher Education in institutional evaluation processes, as well as in the development of short, medium and long-term strategies to ensure timely completion of higher education programmes.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of views and not that of the institution to which they belong.

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Artículo de Investigación | *Bioquímica, Genética y Biología Molecular*

Genotipificación en introducciones de *Capsicum chinense* Jacq. mediante marcadores moleculares SSR fluorescentes

Genotyping in *Capsicum chinense* Jacq. introductions using fluorescent SSR molecular markers

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Key words:

Chilli; elite genotypes; fluorochromes; genetic variability; molecular analysis.

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Resumen

El objetivo del presente estudio fue utilizar marcadores SSR fluorescentes para seleccionar genotipos con amplia variabilidad genética, entre introducciones de *C. chinense* provenientes de México, Brasil y Colombia. En la genotipificación se empleó la plataforma Applied Biosystems 3730xI (Institute of Biotechnology, Cornell University) y la evaluación del tamaño de los alelos se realizó con el software GeneMapper 3.7 (Applied Biosystems). Los marcadores revelaron un total de 114 alelos con un promedio de 12 alelos por locus. El tamaño de los alelos osciló entre 91 y 341 pares de bases. El número de alelos por locus fue variable, de seis para Hpms 2-24 a 21 para Gpms -161. Las poblaciones estudiadas presentaron un índice de Shannon bajo. Las accesiones con mayor diversidad genética fue Brasil con I= 1.622, mientras las de Colombia fue la menor, con I= 0.995. Los valores medios de Ho fueron de 0.517 para Brasil, 0.317 para Colombia y 0.543 para México. Los valores medios de He fueron, en general, superiores a los observados. La tasa de He más baja se registró en accesiones colombianas (0.491), mientras la más alta en las mexicanas (0.719). El análisis de conglomerados mostró la conformación de tres grupos, diferenciados según el origen geográfico de los genotipos evaluados. Todos los cebadores mostraron bandas reproducibles, lo que demuestra su eficiencia para la cartografía genética y el etiquetado de genes en futuros estudios. El valor PIC refleja que la diversidad alélica y la frecuencia entre los genotipos fueron generalmente altas para los loci SSR probados.

Abstract

The aim of this study was to use fluorescent SSR markers to select genotypes with high genetic variability among *C. chinense* introductions from Mexico, Brazil and Colombia. Genotyping was performed using the Applied Biosystems 3730xI platform (Institute of Biotechnology, Cornell University), and allele size assessment was performed using GeneMapper 3.7 software (Applied Biosystems). The markers yielded a total of 114 alleles with an average of 12 alleles per locus. The size of the alleles ranged from 91 to 341 base pairs. The number of alleles per locus varied from six for Hpms 2-24 to 21 for Gpms -161. The populations studied had a low Shannon index. The accessions with the highest genetic diversity were those of Brazil with I= 1.622 and those of Colombia with I= 0.995. The mean values of Ho were 0.517 for Brazil, 0.317 for Colombia and 0.543 for Mexico. The mean He values were generally higher than those observed. The lowest He value was found in Colombian accessions (0.491), while the highest was found in Mexican accessions (0.719). The cluster analysis showed the formation of three groups, differentiated according to the geographical origin of the genotypes evaluated. All primers showed reproducible bands, demonstrating their efficiency for genetic mapping and gene tagging in future studies. The PIC value reflects that allelic diversity and frequency between genotypes were generally high for the SSR loci tested.

Introducción

El género Capsicum se originó a lo largo de los Andes de occidente a noroccidente de Suramérica y comprende aproximadamente 38 especies silvestres y cultivadas [1-3]. Su expansión ha seguido una dirección de las agujas del reloj alrededor de la cuenca amazónica, hacia el centro, el sur de Brasil y finalmente, hacia el norte de Centroamérica [4-6].

De las especies aceptadas, solo seis son cultivadas: *Capsicum annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, *C. pubescens* y *C. Assamicum*, siendo un recurso con un alto valor económico y hospedero de una gran diversidad genética intra e interespecífica [7-9] Las características de importancia para la selección de genotipos élites comprenden el tipo de fruta, color, forma, sabor y fuentes de compuestos relacionados con la salud, tales como el ácido ascórbico (vitamina C), carotenoides (provitamina A), tocoferoles (vitamina E), flavonoides y capsaicinoides [10-13].

En Colombia, *C. chinense* se cultiva en diferentes pisos térmicos (0-2500 m.s.n.m.), mostrando una amplia plasticidad a las condiciones edafoclimáticas, facilitando así la siembra. Fue una de las principales hortalizas de exportación durante el 2022, colocando en manifiesto la necesidad de promover el mejoramiento de las variedades existentes [14-17].

Varios tipos de marcadores moleculares se han utilizado en estudios de diversidad, filogenéticos y cartografía en *Capsicum*, entre ellos los microsatélites SSR, que demostraron ser particularmente valiosos debido a su carácter co-dominante y multi-alélico [18-21]. La utilización de marcadores moleculares en programas de mejoramiento [22] permitió acelerar la exploración de diversidad y selección genotipos. Mientras los análisis genéticos clásicos han revelado un gran número de genes para rasgos de importancia, las tecnologías de secuenciación y genotipificación de nueva generación, han generado recursos genómicos a gran escala y encontrado la base molecular de caracteres económicamente importantes en el genoma de *Capsicum* [23,24].

Con base en lo anterior, el objetivo principal del presente estudio fue utilizar marcadores SSR fluorescentes para seleccionar genotipos élite con amplia variabilidad genética, con el fin de implementar en un futuro una certificación de origen geográfica para materiales de *C. chinense* a ser empleados en programas de mejoramiento.

Métodos

Material vegetal y aislamiento del ADN

Se utilizaron 45 accesiones de *C. chinense* provenientes de México (seis), Brasil (18) y Colombia (21). Las semillas de cada accesión fueron sembradas en bandejas plásticas con turba, mantenidas en invernadero hasta las tres semanas de edad, donde se tomaron dos hojas por planta, conservadas en nitrógeno líquido hasta la extracción de ADN.

El material vegetal (tejidos jóvenes) se maceró en nitrógeno líquido y se procesó según el protocolo de CTAB modificado [25]. La concentración y calidad del ADN se estimó por el método espectrofotométrico estándar, densidad óptica de 260 y 280nm en espectro UV (Colibrí Titertek Berthold), integrado con electroforesis en gel de agarosa al 0.8%. Las muestras de trabajo se diluyeron en TE 1X 100µL a una concentración de trabajo de 20 $ng.ml^{-1}$.

Amplificación de microsatélites fluorescentes

Se emplearon nueve pares de cebadores SSR fluorescentes, utilizados previamente [26-28] y que presentan un alto contenido de información polimórfica (PIC). Estos se distribuyen a través del genoma de Capsicum, abarcando 9 de sus 12 cromosomas. De acuerdo con su tamaño molecular, se formaron paneles de cuatro marcadores por placa. Las amplificaciones de los SSR con marcaje terminal se realizaron en placas de 96 pozos en un termociclador MultiGene OptMax™.

El coctel para PCR, en un volumen de 20µL, contenía 20 ng de ADN genómico; buffer 1X (10 mM de Tris HCl pH 8.8; 50 mM de KCl, 0.1% de TritonX-100); 0.4 mM de cloruro de magnesio (MgCl2) 2mM; 2 pmol de cada cebador (forward y reverse); 0.75 pmol de cada cebador marcado con fluorocromos (Fam, azul; Pet, rojo; Ned, amarillo y Vic, verde) (ver tabla 1) y 1U de Taq polimerasa. Las condiciones de PCR consistieron en 94°C x 5 min; 94°C x 30s, temperatura de alineamiento (Ta) x 45 s; se repiten 35 ciclos del paso 2 al 4; 1min x 72°C, con una extensión final de 5min x 72°C. La verificación del tamaño de los productos de PCR se realizó en gel de agarosa al 2%. En la genotipificación se empleó la plataforma Applied Biosystems 3730xI (Institute of

Biotechnology-Cornell University, USA). Se procedió posteriormente a evaluar el tamaño de los alelos con el software GeneMapper 3.7® (Applied Biosystems).

Tabla 1. Detalles de los cebadores SSR empleados en la genotipificación de 45 introducciones de *C. chinense* provenientes de Brasil, Colombia y México

ID	Marcador	Secuencia	Referencia	Cromosoma	Posición (cM)	Rango amplificación
1	EPMS397-F	**NED**-GCACCCTCCCAATACAAATC	[25]	P1	145.7	102–117
	EPMS397-R	GATCACGGAGAAAGCAAAGG				
2	Gpms-6 -F	**PET**-CAGAGCACTTGACATGCCTT	[25]	P2	103	122–172
	Gpms-6 -R	GATCTTTATAGTAGCTCATCAATA				
3	Hpms 2–24-F	**FAM**-TCGTATTGGCTTGTGATTTACCG	[26]	P9	58.4	187-205
	Hpms 2–24-R	TTGAATCGAATACCCGCAGGAG				
4	GPMS93-F	**VIC**-ATCCTTGGCGTATTTTGCAC	[25]	P3	162.5	202–268
	GPMS93-R	TTCACTTTGCACACAGGCTT				
5	Epms-310-F	**FAM**-TGGGAAGAGAAATTGTGAAAGC	[25]	P8	58	140–172
	Epms-310-R	AGGAAACATGGTTCAATGCC				
6	Gpms-161-F	**PET**-CGAAATCCAATAAACGAGTGAAG	[25]	P7	131.4	184–259
	Gpms-161-R	CCTGTGTGAACAAGTTTTCAGG				
7	Gpms-165-F	**NED**-GAACAATAATAATTGACAGGACAG	[25]	P5	116.4	242–317
	Gpms-165-R	AGCCTCGCAGTTTGTTCTTAC				
8	Hpms1-5-F	**FAM**-CCAAACGAACCGATGAACACTC	[26]	P6	63.1	289-323
	Hpms1-5-R	GACAATGTTGAAAAAGGTGGAAGAC				
9	HpmsE013-F	GCGCCAAGTGAGTTGAATTGAT	[27]	P10	18.1	256
	HpmsE013-R	**VIC**-GCGCCAAGTGAGTTGAATTGAT				

Análisis de datos

Se registró el rango de amplificación de los productos de los SSR evaluados, generando la matriz de datos. Se utilizó el software Genetix 4.05® para calcular el número de alelos efectivos (Ne), heterocigosidad observada (Ho), heterocigosidad esperada (He), índice de información de Shannon (I), estimación de Nei de diversidad genética y heterocigosidad imparcial (UHe). Los valores de PIC para cada SSR se estimaron determinando la frecuencia de alelos por locus usando la siguiente fórmula:

$$PIC = 1 - \sum x_i^2$$

Dónde:

Pi= frecuencia del alelo *i* para el locus estudiado
Pj= frecuencia del alelo (*i*+1)

Valores superiores a 0.5 se consideran muy informativos, los valores entre 0.25 y 0.5 medianamente informativos y los valores inferiores a 0.25 poco informativos. La versión del software DARwin 6.0.1.4® se empleó para realizar el Análisis de Componentes Principales (ACP); la construcción del árbol de disimilitud (dendrograma), por el método de agrupamiento de vecinos no ponderados (NJ), para una matriz de disimilitud calculada con el coeficiente de Jaccard y valores de *bootstrap* de 1000 réplicas.

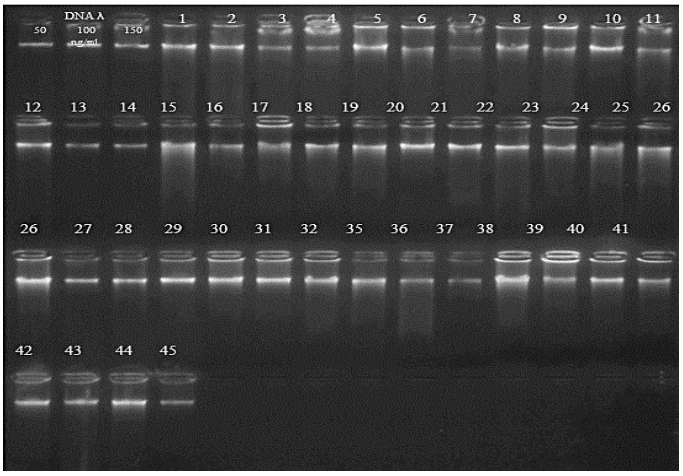
Resultados

Cuantificación del ADN

El protocolo de CTAB modificado [25] demostró una alta eficiencia en la extracción de ADN. La cuantificación en el espectrofotómetro (Colibrí Titertek Berthold) permitió

cuantificar concentraciones desde 5 a 982 ng.ml^{-1}. La lectura en la densidad óptica a 260 y 280 nm, expresó que el ADN era adecuado para su amplificación por PCR (ver figura 1).

Figura 1. Evaluación de la cantidad y calidad de ADN de *C. chinense* mediante la comparación de la intensidad fluorescente del ADN extraído, comparado con tres diluciones de cantidades conocidas de ADN del fago Lambda (50ng, 100ng y 150ng, respectivamente). Gel de agarosa 0.8% teñida con gel red 1x



Análisis moleculares

Se utilizó un total de nueve pares de marcadores SSR (ver tabla 2) empleados para analizar la variación genética en 45 accesiones de *C. chinense*. Los marcadores revelaron un total de 114 alelos, con un promedio de 12 alelos por locus. El tamaño de los alelos osciló entre 91 y 341 pares de bases. El número de alelos por locus fue variable, de seis para Hpms 2–24 a 21 para Gpms-161.

El número efectivo de alelos (Ne) osciló entre 1.65 (HpmsE013) y 9.43 (EPMS397), con un promedio de 4.20 para los nueve cebadores (tabla 3). El índice de información de Shannon (I) osciló entre 0.56 (Hpms 2–24) y 2.28 (EPMS397), promedio de 1.42. Los valores de heterocigosidad observada (Ho) oscilaron entre 0.18 (HpmsE013) y 0.68 (EPMS397 y Gpms-161), promedio de 0.46. La heterocigosidad esperada (He) osciló entre 0.30 (HpmsE013) y 0.88 (EPMS397), promedio de 0.63. La heterocigosidad imparcial (UHe) varió de 0.30 (HpmsE013) a 0.92 (EPMS397), promedio de 0.66. El índice de fijación genética (F) varió de 0.12 (GPMS93) a 0.55 (Hpms1-5), promedio de 0.28. Finalmente, el PIC (contenido de información polimórfica) varió entre 0.41 (Hpms 2–24) y 0.98 (EPMS397), con un promedio de 0.7 (PIC> 0.5), lo que indicó que estos loci contenían una cantidad considerable de información genética que puede utilizarse en estudios de diversidad genética en germoplasma de Capsicum.

Tabla 2. Diversidad genética estimada mediante la evaluación de 9 microsatélites en 45 accesiones de *C. Chinense*. NE- Número efectivo de alelos, I- índice de información de Shannon, Ho- heterocigosidad Observada, He- heterocigosidad Esperada, UHe- heterocigosidad esperada imparcial, F-índice de fijación

Locus	**Ne**	**I**	**Ho**	**He**	**uHe**	**F**	**PIC**
EPMS397	9.43	2.28	0.68	0.88	0.92	0.23	0.98
Gpms-6	3.47	1.48	0.55	0.66	0.69	0.16	0.69
Hpms 2–24	1.66	0.56	0.21	0.32	0.33	0.34	0.41
GPMS93	4.54	1.70	0.65	0.75	0.79	0.12	0.81
Epms-310	4.07	1.48	0.58	0.75	0.79	0.23	0.71
Gpms-161	5.69	1.99	0.68	0.82	0.86	0.17	0.83
Gpms-165	2.27	0.99	0.26	0.44	0.45	0.40	0.62
Hpms1-5	5.01	1.67	0.34	0.76	0.79	0.55	0.81
HpmsE013	1.65	0.60	0.18	0.30	0.30	0.31	0.44
Media	4.20	1.42	0.46	0.63	0.66	0.28	0.7
DS	2.44	0.59	0.21	0.22	0.23	0.14	0.18

Diversidad genética de las poblaciones evaluadas

La tabla 3 resume los índices de diversidad genética de las poblaciones Brasil, Colombia y México. Estas presentaron un índice de Shannon bajo. Las accesiones de *C. chinense* con mayor diversidad genética fueron de Brasil (I=1.622), mientras que las de Colombia presentaron la menor (I=0.995). Los valores medios de Ho entre las poblaciones fueron de 0.517 para Brasil, 0.317 para Colombia y 0.543 para México. Los valores medios de He fueron, en general, superiores a Ho. La tasa de He más baja se registró en las accesiones colombianas (0.491), mientras que la más alta se presentó en las accesiones mexicanas (0.719). La estimación del coeficiente de endogamia (f) varió en las tres poblaciones analizadas.

Tabla 3. Resumen de los índices de diversidad poblacional promediados en nueve loci. Ne = número de alelos efectivos = 1/(Sum pi ^ 2), I = Índice de Shannon = -1*Suma (pi * Ln (pi)), Ho = heterocigosidad observada = Nº de hets/N, He = heterocigosidad esperada = 1- Suma pi ^ 2; UHe = heterocigosidad esperada imparcial = (2N/(2N-1)) * He, F = Índice de fijación = (He - Ho)/He = 1 - (Ho/He)

Población		Ne	I	Ho	He	UHe	F
Brasil	Media	4.939	1.622	0.517	0.687	0.705	0.229
	SE	1.218	0.223	0.062	0.069	0.071	0.065
Colombia	Media	3.168	0.995	0.317	0.491	0.529	0.361
	SE	0.679	0.265	0.085	0.125	0.135	0.032
México	Media	4.490	1.634	0.543	0.719	0.740	0.253
	SE	0.731	0.159	0.073	0.050	0.052	0.082

Estructura genética

El análisis de las variaciones moleculares (AMOVA) indicó que la variación genética dentro de los grupos contribuyó con el 65%, más a la diversidad genética que entre los grupos (8%) respectivamente (tabla 4), según la distribución geográfica de los genotipos.

Tabla 4. Análisis de la varianza molecular (AMOVA) para accesiones de *C. chinense*, utilizando marcadores SSR

Grupos	d.f.	SS	MS	Est. Var.	%
Entre grupos	2	24.124	12.062	0.287	8%
Entre individuos	42	170.709	4.065	0.916	27%
Dentro de individuos	45	100.500	2.233	2.233	65%
Total	89	295.333		3.436	100%

La diferenciación genética entre las poblaciones (FST = 0.084 en *P* <0.001) fue significativa como se indica en la prueba de aleatorización Pairwise FST, con valores de distancia genética entre todas las poblaciones significativos (P<0,01) (ver tabla 5).

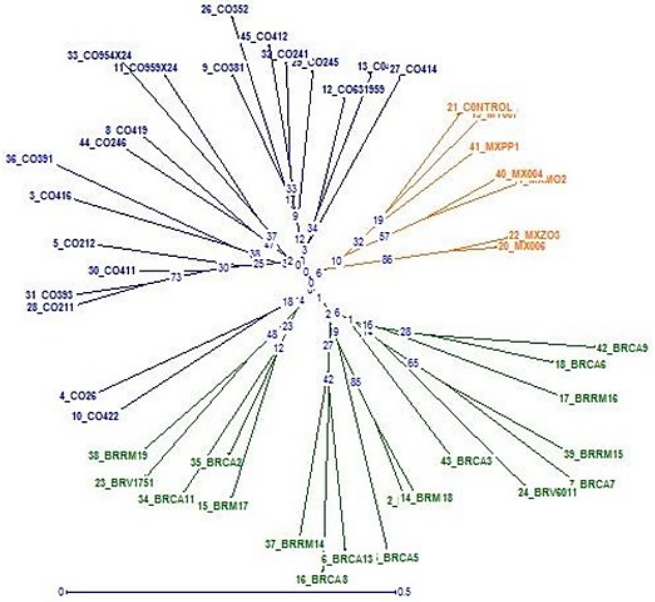
Análisis de conglomerados

Todas las 45 accesiones de *C. chinense* fueron discriminadas con éxito por los SSR seleccionados. Estas se clasificaron en tres grupos, siendo posible la diferenciación sobre la base de origen geográfico para cada una de los genotipos evaluados. El primer grupo lo conformaron 20 accesiones colombianas, el segundo, siete accesiones mexicanas y el tercer, 18 accesiones brasileñas (ver figura 2).

Tabla 5. Estadísticos F de Wright para nueve loci dentro de tres poblaciones de *C. chinense*

F-Statistics	Value	P(rand >= data)
Fst	0.084	0.001
Fis	0.291	0.001
Fit	0.350	0.001

Figura 2. Dendrograma de las relaciones genéticas entre 45 introducciones de *C. chinense* basadas en el polimorfismo SSR. Análisis de clúster según el método neighbour-joining

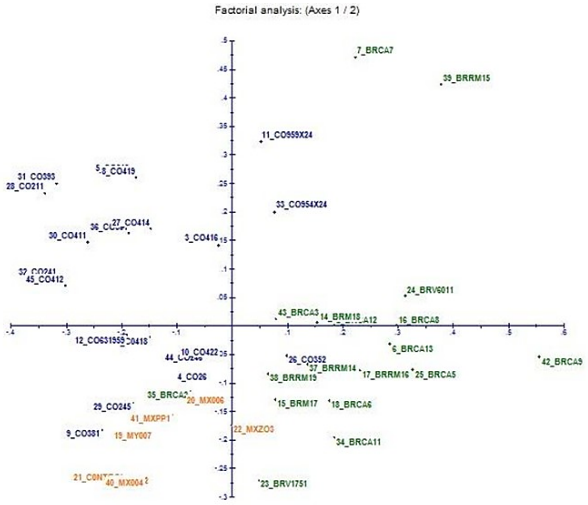


Análisis de coordenadas principales

Los datos SSR fueron sometidos a PCoA con el fin de obtener una visión alternativa de las relaciones filogenéticas entre las introducciones evaluadas (figura 3). En el PCoA bidimensional, las accesiones de *C. chinense* se dividieron en tres grupos siguiendo el origen geográfico. Se demostró que existe gran diversidad genética en los grupos evaluados. Las introducciones exhibieron una distribución uniforme a través de los ejes, similar al patrón mostrado por el dendrograma (figura 3).

En PCoA todas las variedades fueron etiquetadas con diferentes colores sobre la base de sus diferentes regiones, para indicar su especificidad de región.

Figura 3. Análisis de Componentes Principales basado en autovalores calculados a partir de nueve marcadores SSR. Las 45 introducciones se agruparon en tres poblaciones geográficas, mostrados en diferentes colores



Discusión

La diversidad genética de 45 introducciones de *C. chinense* se evaluó utilizando nueve marcadores micro satélites. El nivel de polimorfismo entre las poblaciones evaluadas fue relativamente alto, oscilando entre 66% y 100% con un promedio de 88%. Este alto nivel de polimorfismo en genotipos de *C. Chinense* indica que es una especie altamente polimórfica. La mayoría de los cebadores evaluados fueron altamente informativos, excepto los marcadores Hpms 2–24 y HpmsE013. Todos los cebadores exhibieron bandas reproducibles, lo que demuestra su eficiencia para uso en la cartografía genética y el etiquetado de genes en futuros estudios.

El número de alelos detectados por locus y la naturaleza de los alelos presentes en la población son signos fundamentales de presencia de diversidad alélica. El valor PIC refleja la diversidad alélica; la frecuencia entre los genotipos evaluados fue generalmente alta para todos los loci SSR probados. Estudios relacionados [29-31] indican que los marcadores basados en micro satélites son herramientas poderosas para describir las diferencias y similitudes genéticas y la diversidad entre los genotipos de Capsicum estudiados, favoreciendo la toma de decisiones para futuros programas de mejoramiento.

Considerando el índice de riqueza y diversidad alélica, la variación de los valores dentro de cada uno de los tres grupos evaluados, Brasil, Colombia y México (0.687, 0.491, 0.719, respectivamente), son congruentes y un indicativo de que la diversidad genética puede ser debida al constante flujo génico entre genotipos distintos. A su vez, el dendrograma y el ACP reflejan una cantidad considerable de variación genética total entre los genotipos estudiados, con agrupación en tres grupos principales, y sus subgrupos.

El presente estudio reveló la diversidad genética dentro de una colección de germoplasma de C. chínense de diferentes regiones geográficas. Los SSR fluorescentes permitieron la discriminación de los genotipos con base a su origen eco geográfico, en especial marcadores SSR tales como el EPMS397, GPMS93, Epms-310 y Gpms-161.

Conclusión

El presente estudio ha logrado cumplir de manera satisfactoria con su objetivo principal, que consistía en emplear marcadores SSR fluorescentes con el propósito de identificar genotipos élite que posean una amplia variabilidad genética en materiales de *C. chinense*. Esta estrategia, diseñada con miras a futuras certificaciones de origen geográfico en programas de mejoramiento, ha demostrado su potencial para revolucionar las estrategias de selección en el campo del Fitomejoramiento.

La utilización de marcadores SSR fluorescentes ha revelado un panorama más completo y detallado de la diversidad genética presente en las poblaciones estudiadas. Esta herramienta ha superado las limitaciones de las técnicas convencionales, permitiendo un análisis más profundo y preciso de la estructura genética de los genotipos evaluados. Los resultados obtenidos han arrojado una rica variedad de perfiles genéticos, confirmando la eficacia de los marcadores SSR fluorescentes para discriminar entre genotipos con similitudes morfológicas, pero con diferencias genéticas sustanciales.

La implementación de esta estrategia en programas de Fitomejoramiento abre nuevas puertas hacia la obtención de cultivares altamente mejorados. La identificación de genotipos élite con amplia variabilidad genética es el primer paso hacia la generación de variedades con rasgos innovadores de productividad y calidad del fruto. Estos rasgos, esenciales para una producción sostenible y para

mantener la competitividad en el mercado, son el resultado directo de la profundización en la comprensión de la diversidad genética a través de la tecnología de marcadores SSR fluorescentes.

En conclusión, el análisis de diversidad genética utilizando marcadores SSR fluorescentes ha demostrado ser una herramienta crucial y eficaz para optimizar las estrategias de selección en programas de Fitomejoramiento. Los avances obtenidos mediante esta técnica abren un camino prometedor hacia la creación de cultivares mejor adaptados, más productivos y de mayor calidad. Así, esta investigación no solo satisface su objetivo inicial de identificar genotipos élite con variabilidad genética en *C. chinense*, sino que también tiene el potencial de revolucionar la industria agrícola al proporcionar las bases para una mejora genética más precisa y eficiente.

Consentimiento de publicación

Los autores leyeron y aprobaron el manuscrito final.

Conflicto de interés

Los autores declaran no tener conflicto de interés. Este documento solo refleja sus puntos de vista y no el de la institución a la que pertenecen.

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Estudio de Caso

Ciencias Ambientales

Sustentabilidad ambiental universitaria: Estrategias y percepciones en la UNACH. Un estudio de caso

Environmental sustainability at the university: Strategies and Perceptions at UNACH. A case study

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Resumen

El objetivo del estudio fue identificar y analizar las estrategias y acciones que respaldan la educación ambiental y la percepción universitaria con respecto a la cultura ambiental promovida en la Escuela de Ciencias Administrativas Campus Arriaga de la Universidad Autónoma de Chiapas (México). El enfoque radica en explorar la contribución de esta institución hacia la cultura ambiental, mediante el despliegue de su currículo y acciones correspondientes. La investigación adopta un enfoque descriptivo, basado en un estudio de caso. El análisis se construye en torno a tres fuentes de información cruciales: i) Documentos del Proyecto Académico "Reforma para la Excelencia 2018-2022", Plan de Desarrollo Institucional y Plan de Estudios de la escuela; ii) Proyectos de investigación o extensión realizados en la unidad académica; y iii) Entrevistas con miembros de la comunidad universitaria. A través de 37 entrevistas con docentes, directivos, administrativos y estudiantes, se exploró la percepción respecto al tema ambiental. Los resultados evidencian la presencia de ocho unidades de competencia centradas en el tema ambiental, divididas entre las Licenciaturas en Contaduría y Administración. Además, se han implantado 23 acciones de largo plazo entre 2011 y 2023, junto a cinco proyectos de investigación implementados y cuatro productos académicos (ponencia, artículo y capítulos de libro) relacionados con el ámbito ambiental. Los hallazgos confirman que los participantes perciben que ambos programas educativos implementan actividades para fortalecer la cultura ambiental. Esto permite concluir que: a) las funciones sustantivas (docencia, investigación y extensión) y las acciones intrauniversitarias (Institucional y Escuela) impactan positivamente en la apropiación de la cultura ambiental entre la comunidad universitaria; y b) que la Escuela como ente generador de conocimientos y formadora de profesionales, enfoca sus esfuerzos para la formación integral con un alto sentido de responsabilidad y conciencia ambiental.

Abstract

The aim of the study was to identify and analyse the strategies and actions that support environmental education and the university's perception of the environmental culture promoted at the School of Administrative Sciences, Arriaga Campus, of the Autonomous University of Chiapas (Mexico). The focus is on exploring the contribution of this institution to environmental culture through the use of its curriculum and related actions. The research adopts a descriptive approach based on a case study. The analysis is based on three main sources of information: *i*) documents of the Academic Project "Reform for Excellence 2018-2022", the Institutional Development Plan and the curriculum of the school; *ii*) research or extension projects carried out in the academic unit; and *iii*) interviews with members of the university community. Through 37 interviews with teachers, managers, administrators and students, the perception of environmental issues was explored. The results show the existence of eight competence units focused on the environmental theme, divided between the Bachelor's degrees in Accounting and Administration. In addition, 23 long-term actions were implemented between 2011 and 2023, together with five research projects and four academic products (papers, articles and book chapters) related to the environment. The results confirm that the participants perceive that both educational programmes implement activities to strengthen environmental culture. This leads to the conclusion that: a) the substantive functions (teaching, research and extension) and intra-university actions (institutional and school) have a positive impact on the appropriation of environmental culture within the university community; and b) the school, as a knowledge-generating and professional training entity, focuses its efforts on comprehensive training with a high sense of responsibility and environmental awareness.

Introducción

Durante la revolución industrial, se implantó un modelo de crecimiento y desarrollo centrado en la producción de bienes y posteriormente se orientó al mercado, que privilegia al consumo en detrimento de la conservación de los recursos base, los cuales sustentan la producción de materias primas para la creación de bienes y servicios de la sociedad [1]. No obstante, siglos después, esta concepción de la actividad humana ha intensificado el impactado de manera directa o indirecta en el ambiente para desencadenar crisis globales o regionales no solo desde el punto de vista ambiental, sino también de índole económica, política y sanitaria. Diversos estudios realizados, indican que la explotación desmedida de los recursos naturales ha propiciado el rompimiento o desbalance de muchas de las relaciones e interacciones que regulan el equilibrio ambiental a nivel mundial [2].

En términos prácticos, la mayoría de los recursos naturales son de regeneración lenta o son no renovables, si se tiene en cuenta la intensidad de su empleo y los patrones de consumo por parte de la sociedad moderna. En este sentido, uno de los problemas más importantes por atender, es la complejidad en las formas de pensar y actuar de las personas hacia estos y, por ende, su actitud o posicionamiento ante el medio ambiente [3,4].

Para tener una comprensión holística del problema ambiental, es necesario revisar diferentes posicionamientos teóricos que se pueden considerar complementarios. En este caso, resultan relevantes la teoría del metabolismo social [5], la teoría de la complejidad y pensamiento complejo [6] y la teoría de cambio [7] entre las más importantes. El metabolismo social como teoría, aporta y articula conceptos importantes en las relaciones sociedad-naturaleza como lo son, apropiación, transformación, circulación, consumo y excreción desde las dimensiones: material-tangible e inmaterial-intangible [8]. Por su parte, la teoría de la complejidad asume en los procesos de análisis conceptos como la incertidumbre, la contradicción, el azar, la temporalidad, la emergencia y la auto-organización [9]. Finalmente, la teoría de cambio, conceptualiza elementos importantes para monitorear la acción sensible al contexto para los procesos de desarrollo.

Estos aportes teóricos y conceptuales son esencialmente desafiantes al ser incorporados a la praxis social. Los entornos académicos para la investigación y la docencia requieren romper paradigmas e ideas fuertemente arraigadas para generar el cambio cultural que se corresponde con los mecanismos que permiten la adaptación social a un nuevo contexto, caracterizado por las crisis periódicas y la necesidad impostergable de conservar y regenerar el medio ambiente [10].

Desde la Declaración de Río sobre el Medio Ambiente y el Desarrollo [11], emitida por la Organización de las Naciones Unidas (ONU) y ratificada por sus miembros, establecieron una alianza mundial con la finalidad de promover acciones de protección al sistema ambiental y de desarrollo mundial. Ahí, se reconoció la importancia de la cooperación de los Estados, los sectores claves de la sociedad y las personas, mediante la proclamación de los principios relacionados al medio ambiente. Entre ellos, se destacó el principio X, el cual estipula la participación de todos los ciudadanos en cualquier nivel; mientras que el principio XXI, buscó promover la movilización de los jóvenes para el logro del desarrollo sostenible; en el principio XXVII, se señaló la incumbencia de todos para cooperar solidariamente en la aplicación de los principios de esta Declaración [11].

A pesar de que se han logrado avances importantes, aún existen vacíos en algunos temas por atender en diversas partes del mundo, sobre todo en lo relacionado con la salud, el ambiente, la educación y el desarrollo económico, especialmente en las regiones más marginadas y frágiles del mundo. Por ello, en septiembre de 2015, diversos líderes mundiales adoptaron una serie de objetivos globales con la intención de erradicar la pobreza y proteger el planeta a través de la Agenda 2030, que considera 17 Objetivos de Desarrollo Sostenible para un plazo de 15 años, la cual reconoce la importancia de la participación de todos los sectores de la sociedad para lograrlos.

Entre estos objetivos, el número cuatro, está centrado en lograr una educación de calidad, una parte importante del resto, dirigen su atención hacia temas ambientales mientras que unos pocos se centran en el desarrollo social y económico [12]. Por su parte, el gobierno de México en el Plan Nacional de Desarrollo 2019–2024, se comprometió a impulsar el desarrollo sostenible sin afectar la diversidad cultural ni el entorno [13], lo cual denota la preocupación y ocupación del Estado por tratar estos temas.

En la Universidad Autónoma de Chiapas, México a través del Proyecto Académico “Reforma para la Excelencia

2018-2022", el Plan de Desarrollo Institucional 2030 y el Plan Ambiental implementado a partir del año 2006, se definió una política institucional para atender con responsabilidad social, el fomento de la cultura ambiental para la formación integral del estudiante.

De esta forma, se han (re)diseñado e implementado programas educativos y proyectos especiales en todas las Facultades, Escuelas, Centros, Institutos y áreas que la integran, entre las cuales, se puede mencionar, la Escuela de Ciencias Administrativas Campus Arriaga, que consta en su plan de estudios con dos programas educativos: Licenciatura en Contaduría y Licenciatura en Administración, implementados desde el año 2017, se incorporaron unidades de competencia (materias o asignaturas) con contenidos ambientales. A la par, se han efectuado proyectos y acciones estratégicas como parte de las funciones sustantivas y acciones intrauniversitarias, encaminadas a atender puntualmente la formación integral del estudiante con una cultura ambiental sólida.

Esto, con la firme intención de reconocer y atender el compromiso social de la universidad en la formación de profesionales competentes y capaces de afrontar el desafío de la sostenibilidad de su entorno. En este tenor, el objetivo de la presente investigación fue analizar, dentro de las funciones sustantivas e intrauniversitarias de la Escuela de Ciencias Administrativas, las estrategias y acciones que sustentan la educación ambiental en la oferta educativa, así como la percepción de la comunidad universitaria respecto a la cultura ambiental fomentada.

Métodos

Contexto y objetivo del estudio

Este estudio tuvo lugar en la Escuela de Ciencias Administrativas de la UNACH, situada en el municipio de Arriaga, Chiapas-México. El objetivo primordial fue examinar las estrategias y acciones que respaldan la educación ambiental en la oferta educativa, además de explorar la percepción de la comunidad universitaria en relación con la cultura ambiental promovida en dicho entorno.

Enfoque y diseño de la investigación

La investigación adoptó un enfoque cualitativo de tipo descriptivo, utilizando un estudio de caso como método central.

Contexto institucional y recopilación de datos

En el período de los últimos cinco años, según los registros del Sistema Integral de Administración Escolar (SIAE), este plantel ha mantenido una matrícula promedio de 256 estudiantes, con un equipo de 16 profesores [14]. La información relevante para este estudio fue obtenida de fuentes diversas:

i. Documentos del Proyecto Académico: "Reforma para la Excelencia 2018-2022"; Plan de Desarrollo Institucional y Plan de Estudios implementado en la Escuela.
ii. Proyectos de investigación o extensión académica llevados a cabo en la ECA-Arriaga.
iii. Entrevistas cualitativas con miembros de la comunidad universitaria.

Esta variedad de fuentes permitió una comprensión profunda y holística de las estrategias de educación ambiental y la percepción de la cultura ambiental en el contexto universitario.

Ejes de gestión de la información

La gestión de información se centró en los siguientes ejes:

i. Acciones orientadas a la educación ambiental en la ECA-Arriaga, en función del marco institucional 2018-2022.
ii. Integración del tema ambiental en los planes de estudio.
iii. Desarrollo de proyectos relacionados con el medio ambiente en la ECA-Arriaga, en consonancia con el marco institucional (2018-2022).
iv. Implementación de acciones intrauniversitarias y de vinculación para el fomento de la cultura ambiental en la ECA-Arriaga, siguiendo el marco institucional (2018-2022).
v. Exploración de las percepciones de la comunidad universitaria respecto a las acciones, estrategias o proyectos ambientales implementados.

Estos ejes constituyen el marco desde el cual se analizó y evaluó la relación entre educación ambiental, percepción de la cultura ambiental y las acciones institucionales en la Escuela de Ciencias Administrativas.

Las entrevistas, como componente crucial de esta investigación, se llevaron a cabo durante el período de noviembre de 2022 a enero de 2023. La muestra fue

seleccionada de manera no probabilística, considerando los siguientes actores clave:

Docentes

Se realizaron diez entrevistas enfocadas en las experiencias investigativas, actividades y productos que han influido en la formación de la cultura ambiental de docentes, estudiantes y administrativos de la Escuela. Se identificaron proyectos específicos, su vigencia, el tipo (investigación o extensión), los docentes colaboradores, el número de estudiantes involucrados y las asignaturas relacionadas.

Estudiantes

Se llevaron a cabo 27 entrevistas para recopilar información sobre las acciones emprendidas por los estudiantes universitarios en beneficio del entorno ambiental. Se identificaron las acciones, su vigencia, el tipo (colaborativas, intrauniversitarias o de vinculación), las personas responsables y los logros alcanzados.

Administrativos y directivos

Cuatro entrevistas abordaron los temas tratados tanto con docentes como con estudiantes. El procesamiento de la información primaria y secundaria incluyó la categorización de respuestas, así como el análisis y la síntesis de la información obtenida de manera exhaustiva durante el proceso de investigación.

Fuentes documentales analizadas (Tabla 1)

En el proceso de investigación, se ha recurrido a una variedad de fuentes documentales que en conjunto, brindan una visión integral y detallada del contexto institucional. Estas fuentes, presentadas en la tabla 1, proporcionan información crucial para comprender la dinámica y los enfoques en la Universidad Autónoma de Chiapas (UNACH)-México.

Proyecto Académico "Reforma para la Excelencia 2018-2022"

Este proyecto ha contribuido con información esencial relacionada con la situación actual de la Universidad en términos de docencia, investigación, extensión y vinculación. Además, presenta los elementos filosóficos y estratégicos, incluyendo la misión y visión institucional. Los programas delineados en el Proyecto guían diversas acciones, abarcando desde el fortalecimiento de la gestión universitaria hasta la creación de una universidad que deja huella [15].

Plan de Desarrollo Institucional-PDI 2030

Este Plan establece de manera articulada las líneas de acción en doce ejes temáticos prioritarios. Incluye aspectos cruciales como la normatividad, la planeación, la organización y la gestión universitaria, así como el modelo educativo y académico. Las políticas específicas se trazan en función de estos ejes, abarcando desde la calidad educativa hasta la infraestructura universitaria [16].

Plan Ambiental Institucional

Este plan define las líneas generales de acción, centradas en la docencia, investigación y extensión. Proporciona un marco de referencia para abordar asuntos ambientales de manera integral y estructurada [17].

Modelo Educativo y Académico

Esta fuente aporta información relevante sobre las funciones sustantivas de la Universidad: docencia, investigación y extensión. Además, aborda la formación integral del estudiante y la responsabilidad social universitaria (RSU), aspectos esenciales para comprender la cultura educativa de la UNACH [18].

Planes de Estudios de Licenciaturas en Contaduría y Administración

Estos planes de estudios detallan las unidades de competencia que incorporan temas ambientales. Esto proporciona una visión específica de cómo se integran los aspectos relacionados con el medio ambiente en las áreas académicas de Contaduría y Administración [19,20].

Estas fuentes documentales han sido fundamentales para contextualizar y enriquecer el análisis de las estrategias y percepciones en torno a la cultura ambiental en la UNACH, permitiendo una comprensión más profunda y precisa de los enfoques y acciones institucionales relacionadas con la educación y la conciencia ambiental.

Tabla 1. Fuente documental revisada

Documentos examinados	Referencia	Observaciones sobre la información aportada
Reforma para la Excelencia 2018 – 2022	UNACH. Proyecto Académico: Reforma para la Excelencia 2018-2022 Universidad Autónoma de Chiapas; 2019.	Presenta la situación actual de la Universidad, elementos filosóficos y estratégicos del Proyecto Académico y los programas que orientan las acciones.
Plan de Desarrollo Institucional-PDI	UNACH. Plan de Desarrollo Institucional 2030 Universidad Autónoma de Chiapas; 2018.	Establecimiento de líneas de acción con doce ejes temáticos prioritarios.
Plan Ambiental Institucional (PAI-UNACH)	UNACH. Plan Ambiental Institucional - UNACH. Universidad Autónoma de Chiapas; 2006.	Líneas generales de acción del plan ambiental institucional (ejes temáticos prioritarios, docencia, investigación y extensión).
Modelo Educativo y Académico	UNACH. Modelo Educativo y Académico Universidad Autónoma de Chiapas; 2020.	Funciones sustantivas (docencia, investigación y extensión), formación integral del estudiante; Responsabilidad Social Universitaria (RSU).
Planes de Estudios de las Licenciaturas en Contaduría y en Administración	[20] UNACH. Plan de Estudios Licenciatura en Administración. Universidad Autónoma de Chiapas; 2017. [21] UNACH. Plan de Estudios Licenciatura en Contaduría. Universidad Autónoma de Chiapas; 2017.	Presencia de temas ambientales.

Resultados

Análisis integral del Proyecto Académico Reforma para la Excelencia 2018-2022, Plan de Desarrollo Institucional y Plan de Estudios impartido en la Escuela

En el total de los documentos institucionales vigentes, se identificaron al menos tres temas ambientales. En este sentido los que abordaron la temática de forma más completa fueron: el Plan ambiental institucional y el Modelo educativo y académico. Esta documentación institucional vincula un conjunto de proyectos, acciones o productos orientados a la educación ambiental. Entre estos, los que más transversalizan son los proyectos de investigación, las acciones intrauniversitarias y las acciones de vinculación (ver tabla 2).

Análisis del Plan de Estudios impartido en la Escuela

La universidad realiza actividades de docencia, investigación y extensión; referente a la docencia se incluyen, en el currículo y sus contenidos de los planes de estudios impartidos en la Escuela, unidades de competencias que se relacionan con el medio ambiente. Los Planes de Estudios de la Licenciatura en Contaduría y Licenciatura en Administración, señalan la formación integral del estudiante con responsabilidad social, compromiso con el desarrollo sostenible del país y de sus comunidades, el aprecio por la cultura y atención al entorno.

Las tablas 3 y 4 muestran el análisis de las áreas de formación, las unidades de competencias, las subcompetencias y los semestres en que se imparten los temas referidos. En ambos planes de estudio, se localizan cuatro unidades de competencias que incluyen temas del medio ambiente que elevan la cultura ambiental durante los estudios universitarios. Los temas ambientales se presentan de forma equilibrada tanto en áreas de formación básica como humanística y disciplinar.

Proyectos de investigación o extensión con el tema ambiental

De acuerdo con las entrevistas realizadas a los docentes, los resultados con respecto al tema ambiental fueron de nueve productos: una ponencia, cuatro UVD, dos capítulos de libros, un artículo y un proyecto de investigación (ver tabla 5).

Estos productos están dirigidos al impacto en el desarrollo local; al aprovechamiento y conservación de los recursos naturales; a generar responsabilidad social ambiental; así como incentivar la adopción gradual y progresiva de acciones individuales y colectivas a favor del medio ambiente del municipio de Arriaga-Chiapas, México.

Tabla 2. Integración de acciones orientadas a la educación ambiental en la ECA-Arriaga en función del marco institucional 2018-2022

Proyecto, acción o productos generados	Proyecto Académico Reforma para la Excelencia	Plan de desarrollo institucional	Plan ambiental institucional	Modelo educativo y académico	Planes de estudios
Unidades de vinculación docente		X	X	X	
Producto de investigación (capítulo de libro, artículo de revista y ponencia)			X	X	X
Proyecto de investigación	X	X	X	X	X
Acciones intrauniversitaria	X	X	X		
Acciones de vinculación	X	X	X	X	X

Tabla 3. Plan de estudios del programa Licenciatura en Contaduría y el tema ambiental

Área de formación	Unidad de competencia	Subcompetencia	Semestre
Finanzas	Seminario de formación y evaluación de proyectos.	Impacto ecológico, social y económico del proyecto de inversión.	Noveno
Elección libre	Contabilidad ecológica.	Contabilidad ecológica en las entidades económicas. Partidas ambientales. Informes financieros ambientales. Contabilidad ambiental con base a la normatividad.	Séptimo
Aprendizaje y conocimiento.	Ética y responsabilidad Social de la Contaduría.	La ética, moral y el medio ambiente.	Quinto
Humanística	Formación para la vida y sustentabilidad.	Responsabilidad ambiental para el desarrollo del pensamiento sustentable.	Segundo

Tabla 4. Plan de estudios del programa Licenciatura en Administración y el tema ambiental

Área de formación	Unidad de competencia	Subcompetencia	Semestre
Formación básica	Seminario de investigación.	Metodología por proyecto (Estudio ambiental).	Octavo
Específica general sub área administración	Plan de negocio.	Estudio técnico (Sustentabilidad del proyecto).	Octavo
Formación básica	Desarrollo sustentable.	Ecología y medio ambiente. Desarrollo sustentable e indicadores de sustentabilidad. Enfoques del desarrollo sustentable.	Tercer
Humanística	Ética y responsabilidad.	La responsabilidad social como parte de la formación ética (Estrategia socio ambiental). Método de tres dimensiones (Desarrollo sustentable).	Primer

Tabla 5. Proyectos y productos relacionados con el tema ambiental en la ECA-Arriaga en función del marco institucional (2017-2022)

Proyecto (Vigencia)	Tipo	Docentes involucrados
Los empresarios y la responsabilidad social (2019)	Ponencia	3 docentes
Líneas de acción para el cuidado del medio ambiente (2019)	UVD	3 docentes
La Importancia y Función de los Manglares en el Municipio de Arriaga, Chiapas (2019)	Capítulo de libro	6 docentes
Acciones favorables al medio ambiente en Arriaga, Chiapas (2018)	UVD	5 docentes
Los recursos naturales, una oportunidad de desarrollo en Playa Ventura (2017)	Artículo de revista	2 docentes
Propuesta de Estrategias de Desarrollo Turístico de Playa Ventura (2017)	Proyecto de investigación	3 docentes
Educación ambiental mediante el desarrollo y fortalecimiento de UMAS en la región Istmo Costa. Caso: Iguana Verde (2017)	Capítulo de libro	5 docentes
Educación Ambiental en las Escuelas del Nivel Medio Superior del Municipio de Arriaga, Chiapas (2008)	UVD	6 docentes
El papel del contador público y su responsabilidad en la contabilidad ecológica de las empresas del municipio de Arriaga, Chiapas (2007)	UVD	7 docentes

Tabla 6. Acciones intrauniversitarias y de vinculación relacionados con el tema ambiental en la ECA-Arriaga en función del marco institucional (2018-2023)

Acciones	Vigencia	Tipo	Participante	Resultados
Curso otorgado por la Dirección de Formación e Investigación Educativa	2023	Intrauniversitaria	Mtro. Javier de la Cruz López (Docente)	Curso recibido "Preservación y Cuidado del Medio Ambiente y sus Implicaciones Prácticas en la Docencia"
Donación y reforestación de plantas de ornato, árboles maderables y frutales	2023	Colaborativa	Dra. Ligia Margarita Domínguez Castañón (Docente)	Reforestación de jardines y área de estacionamiento de la Escuela
Recolecta de botellas y venta semanal para la compra de plantas	2021	Colaborativa	Mtra. Liliana Castellanos Hernández (Docente)	Donación de plantas para el jardín de la Escuela
Donación de plantas de ornato por la comunidad universitaria	2021	Colaborativa	Dirección de la Escuela	Siembra de plantas donadas en el jardín de la Escuela
Curso otorgado por la Dirección de Formación e Investigación Educativa	2021	Intrauniversitaria	Dos docentes participantes: Mtra. Blanca Flor Esquinca Castillejos. Mtro. José Enrique Aguilar Vázquez	Curso recibido "Preservación y Cuidado del Medio Ambiente y sus Implicaciones Prácticas en la Docencia"
Investigación sobre tipo de planta, siembra y seguimiento de crecimiento	2020	Colaborativa	Dra. María Eugenia Estrada Álvarez (Docente)	Siembra de plantas ornamentales por los estudiantes
Identificación de lugares turísticos ecológicos	2020	Colaborativa	Mtro. Javier de la Cruz López (Docente)	Reporte elaborado por estudiantes
Reforestación por motivo del día del Medio Ambiente	2019	Vinculación	Presidencia municipal de Arriaga, Chiapas	Reforestación en la Unidad Deportiva y en la Escuela con la participación de administrativos
Mega operativo de Limpieza Municipal	2019	Vinculación	Presidencia municipal y Jurisdicción Sanitaria VIII	Limpieza de la zona aledaña a la Escuela con la participación de docentes, estudiantes y administrativos.
Limpieza del balneario "Santa Brígida"	2018	Vinculación	Silvia Arreola Figueroa (responsable de medio ambiente)	Recolección de basura de la playa con la participación de docentes, estudiantes, pobladores y personal de la presidencia municipal
Cursos de capacitación, impartido por la Gerencia de Cuencas del Río Lagartero, sobre el medio ambiente, cuidado del agua, cambio climático y residuos sólidos.	2018	Vinculación	Silvia Arreola Figueroa (responsable de medio ambiente)	Cursos recibidos por los estudiantes, administrativos y docentes
Taller de implementación de sistema de riego por goteo impartido por la Gerencia de Cuencas del Río Lagartero	2018	Vinculación	Silvia Arreola Figueroa (responsable de medio ambiente)	Taller recibido por los estudiantes

Tabla 6. Continuación

Acciones	Vigencia	Tipo	Participante	Resultados
Reforestación en el Centro Universitario de Transferencia y Tecnología (CUTT) de la Escuela	2018	Intrauniversitaria	Dirección de la Escuela	Siembra de 6000 árboles maderables
Siembra por el personal administrativo	2018	Intrauniversitaria	Silvia Arreola Figueroa (responsable de medio ambiente)	Huerto de hortalizas
Campaña de Reforestación "Adopta un árbol" con la participación de alumnos	2018	Vinculación	Dra. Ligia Margarita Domínguez Castañón (Docente)	Entrega de árboles a personas que habitan cercana del margen del río Lagartero

Tabla 7. Opiniones o percepciones de la comunidad universitaria sobre las acciones, estrategias o proyectos ambientales implementados

Proyecto, acción o estrategia identificada mencionada	No. de docentes	No. de estudiantes	No. Directivos y Administrativos	Observación
UVD (4)	21	91		Convocatoria UNACH
Capítulos de libros (2)	12			
Artículo de revista (1)	2			
Ponencia (1)	3			Congreso
Proyecto de investigación (1)	3			Registro en DGIP - UNACH
Acciones de vinculación (13)	19	481	68	H. Ayuntamiento municipal y Jurisdicción sanitaria VIII
Acciones Colaborativas (5)	12	105	12	Comunidad de la Escuela
Acciones intrauniversitaria (5)	3	60	30	Comunidad de la Escuela

Acciones intrauniversitarias y de vinculación relacionados con el tema ambiental

La Escuela de Ciencias Administrativas promueve en su misión ser un ente de cambio en los profesionistas que perfeccionen el desarrollo e impulso económico, cultural, social y político de su entorno; por ello la importancia de mantener un vínculo cercano con la población, empresas, institución y autoridades gubernamentales.

En la tabla 6, la ECA-Arriaga en función del marco institucional (2018-2022) durante el periodo 2011-2023, se pone en evidencia el desarrollo de cinco acciones intrauniversitarias, cinco colaborativas y 13 de vinculación. Las acciones extracurriculares impulsadas en la Escuela de Ciencias Administrativas han consistido en reforestación, limpieza y reciclaje PET; así mismo, se otorgaron cursos y talleres a docentes y alumnos impartidos por diversas dependencias gubernamentales y la Universidad Autónoma de Chiapas con el objetivo de inculcar la cultura ambiental.

A partir del año 2017, se ha ejecutado en la unidad académica el programa de universidad saludable, en él, se integra el responsable de medio ambiente, que desarrolla de manera semestral la planeación de actividades; vinculando a la Institución con el gobierno municipal, iniciativa privada y personas interesadas en el tema; en cada una de estas, se incluyen estudiantes, docentes y administrativos.

Entrevistas aplicadas: percepciones universitarias sobre la educación ambiental

A través de las entrevistas, se logró información en cuanto a la realización de cuatro Unidades de Vinculación Docente, con la participación de docentes y alumnos de los diferentes semestres. Los docentes presentaron dos capítulos de libros, un artículo de revista, una ponencia y un proyecto de investigación. Los productos mencionados se enfocaron a temas de responsabilidad social ambiental, desarrollo sustentable, desarrollo local y regional, medio ambiente e impacto ambiental. En el periodo 2011–2023, se efectuaron 13 acciones de vinculación, cinco colaborativas y cinco intrauniversitarias, en ellas participaron docentes, estudiantes y administrativos (ver tabla 7).

Discusión

Los resultados presentados revelan una marcada influencia de las preocupaciones ambientales en el entorno organizacional. La documentación oficial evidencia una profunda integración del tema ambiental en la estrategia de formación, manifestándose en todos los documentos. Además, es notable que al menos un documento como el Plan Ambiental Institucional se dedica exclusivamente a este ámbito. La presencia dominante y simultánea de este tema, tanto de manera transversal como específica en los discursos organizacionales, constituye un indicador de su institucionalización [21]. Este fenómeno se extiende hacia las dimensiones intangibles del proceso de metabolismo social [22]. El enfoque en la conciencia ambiental por parte de las instituciones educativas surge de la convergencia de múltiples factores que, en su conjunto, conforman lo que se identifica como la respuesta social a la "crisis planetaria" [6].

Esta conciencia ambientalista no solo se limita al nivel individual o de grupos sociales, sino que también se refleja en el accionar de organizaciones e instituciones públicas; no obstante, su alcance se expande gradualmente hacia las políticas públicas y los discursos oficiales e institucionales, muchas veces debido a las exigencias normativas y a las presiones que se ejercen desde instancias superiores [23]. En el ámbito de las ciencias administrativas y el mundo empresarial, la normativa ambiental se presenta como un regulador de gran relevancia. Paralelamente, la creciente conciencia colectiva agudiza las demandas y acciones ciudadanas [24]. En este contexto, la inclusión del tema ambiental en la estructura curricular de las disciplinas afines refleja más una adaptación a las demandas formativas contemporáneas que una mera respuesta a las presiones verticales ejercidas por las instituciones.

Esta tendencia se refleja en el caso de estudio analizado, donde se constata la presencia significativa de temáticas ambientales en tres esferas cruciales: *i*) la reestructuración curricular; *ii*) la producción académica y *iii*) las dinámicas internas y las relaciones externas. En el diseño del plan de estudios, los temas ambientales permearon diversas áreas de formación, ya sea en los componentes básicos, disciplinares o humanísticos. Desde una perspectiva de Teoría de Cambio, esta adaptación curricular constituye un efecto directo que debería incidir en las competencias específicas y generales de los graduados [7]. No obstante, su impacto sería más bien una consecuencia indirecta, derivada de estas habilidades, que se manifestaría en un cambio cultural y en la matriz ideológica capaz de movilizar una acción cohesiva, como se observa en la producción académica y las interacciones internas y externas.

La formación holística del estudiante se concreta mediante la sinergia de las funciones fundamentales que engloban la enseñanza, la extensión y la investigación. Estas funciones se amalgaman para propiciar que el estudiante pueda identificar los desafíos sociales y proponer soluciones ambientalmente sostenibles; aquí radica el compromiso tanto de la institución universitaria como de los educadores, quienes deben concebir estrategias esenciales para generar nuevos conocimientos [18]. Con el objetivo de inculcar una cultura ambiental, los planes de estudio de la Escuela de Ciencias Administrativas, incorporan unidades de competencia vinculadas a la educación ambiental, además de contribuir a través de la realización de investigaciones que fomentan la interacción con la sociedad.

Al examinar la esfera de la producción académica y sus resultados como un ámbito de impacto, emergen dos aspectos distintivos: en primer lugar, la responsabilidad social y las funciones profesionales que demuestran sensibilidad hacia las problemáticas ambientales; en segundo lugar, la gestión de los recursos naturales en el contexto empresarial.

La responsabilidad social empresarial se concibe como un compromiso constante de generar beneficios más allá de los confines laborales, abarcando a los trabajadores, sus familias, la comunidad y la sociedad en su conjunto [25]. Por lo tanto, este tipo de iniciativas podría servir como un indicador indirecto de los efectos del cambio en el plan de estudios en el ámbito de la formación humanística. Asimismo, las acciones y productos académicos que abordan temáticas relacionadas con la gestión de recursos naturales están estrechamente vinculados a posibles repercusiones de los componentes ambientales en las áreas curriculares fundamentales y disciplinarias.

En términos generales, esto se traduciría en un impacto sobre el metabolismo social en lo que respecta a la reconfiguración de la concepción de los recursos naturales, abarcando procesos de apropiación, transformación, circulación, consumo y eliminación [22]. En esencia, estamos observando una institución social que asume su responsabilidad de interconectar estas categorías mediante la administración que se promueve

en su estructura curricular, así como en su producción académica, sus vínculos con la comunidad y sus dinámicas internas.

Sin embargo, estos efectos deben extender su influencia en un entorno empresarial y social que se torna cada vez más intrincado. En este entorno, el aumento vertiginoso de la demanda de productos y servicios encuentra un mayor reconocimiento que la importancia de la sostenibilidad, debido a la prevalencia de una racionalidad instrumental [26]. Esta racionalidad instrumental, esencialmente, se centra en la búsqueda de beneficios sin considerar las implicaciones sociales y ambientales asociadas. En esta distinción radica el valor fundamental de la información recopilada acerca de la cultura ambiental promovida por la unidad académica.

No obstante, esta cultura ambiental se encuentra ante el desafío de desafiar la lógica instrumental dentro de un contexto socio-productivo complejo. Esto implica la necesidad de dotar a los individuos con competencias para la acción estratégica en entornos en los cuales los impactos a menudo trascienden los límites del control administrativo, humano y de los objetivos predefinidos [27].

Conclusión

La Escuela de Ciencias Administrativas, ubicada en el Campus Arriaga de la Universidad Autónoma de Chiapas, se erige como un epicentro académico generador de conocimiento y forjador de profesionales comprometidos. Su enfoque en la formación integral y la conciencia ambiental demuestra un sentido de responsabilidad excepcional. Las funciones cruciales de docencia, investigación y extensión, junto con las acciones intrauniversitarias, han moldeado positivamente la asimilación de la cultura ambiental en la comunidad universitaria.

Estas contribuciones sustantivas se alinean armoniosamente con los pilares que guían a la institución. La progresiva consolidación de estos ejes rectores, respaldada por funciones tanto sustantivas como administrativas, no solo fortalece a la universidad, sino que también proyecta influencias positivas hacia la sociedad en el corto y largo plazo.

El compromiso constante con la educación ambiental y la conciencia ecológica ha cristalizado en acciones tangibles y estrategias eficaces; estas han tejido una red interconectada de aprendizaje y compromiso, que abarca desde el diseño curricular hasta la implementación de proyectos y la sensibilización activa de la comunidad. La Universidad Autónoma de Chiapas, a través de la Escuela de Ciencias Administrativas Campus Arriaga, emerge como un faro de sostenibilidad, formando agentes de cambio que trascienden las aulas.

El legado de esta investigación reside en la comprensión profunda y multifacética de cómo la educación ambiental, la percepción universitaria y las acciones institucionales convergen para fomentar una cultura ambiental arraigada. Los hallazgos aquí presentados no solo enriquecen el conocimiento académico, sino que también iluminan un camino hacia la mejora constante y la proyección positiva de la universidad en su entorno y más allá.

Consentimiento de publicación

Los autores leyeron y aprobaron el manuscrito final.

Conflicto de interés

Los autores declaran no tener conflicto de interés. Este documento solo refleja sus puntos de vista y no el de la institución a la que pertenecen.

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Indicators for agroecological transition: Food security, nutrition, well-being, promotion of a sustainable food model

Indicadores para la transición agroecológica: Seguridad alimentaria, nutrición, bienestar, promoción de un modelo alimentario sostenible

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Abstract

Agroecology is a viable alternative confronting the impressive model of industrial agriculture. To project the concept of Agroecology beyond theoretical definitions to practical and quantifiable principles, it is necessary to have analysis, communication and evaluation tools that support and allow the evaluation of positions. Indicators are quantifiable tools that make the obtention of numerical variables possible to compare the different models. This study aims to establish a proposal of quantifiable indicators to evaluate the direct impact of aspects related to food and nutritional quality, responding to the demand for an integrated evaluation of agroecological systems, thus improving the tools for calculating current indicators. The proposed parameters cover aspects that have a greater or lesser impact on the daily diet, such as the variability of the foods that make up the dish, their contribution to food safety, the nutritional composition and bioactive components, organoleptic aspects, degree of processing and transformation of the food consumed, environmental aspects that influence the production model and their influence on human well-being. As well as parameters of the social sphere, such as the impact on the economy of scale, on attributes of proximity, temporality, as well as indicators related to social justice. The proposal can help to obtain assessment before or after the implementation of agricultural policies towards the agroecological transition, allowing self-assessment, and provide verifiable data after a change in agricultural policies when redesigning or introducing agroecological strategies.

Resumen

La Agroecología es una alternativa viable frente al impresionante modelo de agricultura industrial. Para proyectar el concepto de Agroecología más allá de definiciones teóricas hacia principios prácticos y cuantificables, es necesario contar con herramientas de análisis, comunicación y evaluación que apoyen y permitan valorar las posturas. Los indicadores son herramientas cuantificables que posibilitan la obtención de variables numéricas para comparar los diferentes modelos. Este estudio pretende establecer una propuesta de indicadores cuantificables para evaluar el impacto directo de aspectos relacionados con la calidad alimentaria y nutricional, respondiendo a la demanda de una evaluación integrada de los sistemas agroecológicos, mejorando así las herramientas de cálculo de los indicadores actuales. Los parámetros propuestos abarcan aspectos que inciden en mayor o menor medida en la dieta diaria, como la variabilidad de los alimentos que componen el plato, su contribución a la seguridad alimentaria, la composición nutricional y componentes bioactivos, aspectos organolépticos, grado de procesado y transformación de los alimentos consumidos, aspectos ambientales que influyen en el modelo productivo y su influencia en el bienestar humano. Así como parámetros de la esfera social, como el impacto en la economía de escala, en atributos de proximidad, temporalidad, así como indicadores relacionados con la justicia social. La propuesta puede ayudar a obtener una evaluación antes o después de la aplicación de las políticas agrícolas hacia la transición agroecológica, permitiendo la autoevaluación, y proporcionar datos verificables después de un cambio en las políticas agrícolas al rediseñar o introducir estrategias agroecológicas.

Introduction

The different proposals for a common definition of Agroecology, conclude that this concept brings together the science that manages sustainable food systems, the technique based on environmentally friendly ecological practices and the social movement that promotes the transition to fair and sovereign food systems [1-4]. In some circles, Agroecology is often seen as a side-thinking discourse, which can help close the current gaps between conventional and organic farming, for example. The members of the agroecological movement do not accept these trends, since they may cause confusion, ignoring the existence of an agroecological movement or the scientific discipline that grows alongside it, with organic agriculture as a productive base.

Herren et al. [5] wrote that "agroecology is neither a defined system of production nor a production technique. It is a set of principles and practices intended to enhance the sustainability of a farming system, and it is a movement that seeks a new way of food production. Increasingly, agroecology is a science looking at ways of transforming the existing food system, and of further developing agriculture and adapting it to the changing environment – an approach which is vital for food security", incorporating aspects related to food safety in the definition. Previously, De Schutter [6] in his report presented at the 16th session of the United Nations Human Rights Council, also established links between agroecology and food, nutrition and food security, identified agroecology as a model of agricultural development that increases productivity at the field level, reduces rural poverty and contributes to improved nutrition. He also points out that the concept of agroecology includes the participation and empowerment of groups in food insecurity, since it is impossible to improve their situation without involving them in the process.

From the definitions of the early stages [7], as well as the most current ones, agroecology is a dynamic concept, evolving its meanings, thoughts, interpretations and approaches from the 20th century to the present day [8-10] where its nuances have increased and in response to the concerns and priorities that the different institutions and countries express and specify about agroecology. These definitions recognize the transdisciplinary nature of the agroecological concept which encompasses ecologically based agricultural science, a set of practices, and a social and even political movement. Thus, one of the most complete definitions of Agroecology is that of "Ecology of the food system" [11].

In 2009, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) documented the need for agroecological transformation of agriculture [12], food production and consumption and positioned the concept of agroecology in the global food policy debate. To project the concept of Agroecology beyond the theoretical definitions to the practical and quantifiable principles, it is necessary to have analysis, communication and evaluation tools that support and enable evaluating the positions. Indicators stand out among these tools.

An indicator is a qualitative and/or quantitative variable that allows identifying the starting point and corrective actions in decision-making [13]. The indicators are being used to identify successful agroecological experiences to scale them up, and promote greater political and financial support for agroecology [14-17]. It used of indicators on environmental, social, cultural and economic dimensions of agroecology at different spatial scales (field, agroecosystem, whole food system).

FAO [3] has established an analytical tool that includes 10 interrelated and interdependent elements to facilitate agroecological transformation: diversity, synergies, efficiency, resilience, recycling a co-creation and exchange of knowledge (describing common characteristics of agroecological systems, basic practices and innovation criteria); human and social values and food culture and traditions (revealing contextual aspects); the circular and solidarity economy and responsible governance (addressing with the enabling environment). In response to the methodological challenge of being able to use the 10 elements of agroecology as criteria and indicators for monitoring the agroecological transition, FAO has coordinated the participatory development of the Tool for Agroecology Performance Evaluation (TAPE), whose general objective is to generate consolidated evidence on the extent and intensity of the use of agroecological practices and the performance of agroecological systems across five dimensions of sustainability: environment, social and cultural, economic, health and nutrition, and governance [3,18].

The report entitled: "Agroecology and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition" by the High-

Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security [19], calls for a reorientation of investments and global efforts to design and implement models that open pathways to sustainable food systems. To this end, the report places agroecology at the center, a concept that includes practices that improve biological processes in agricultural production, the reduction of the use of fossil fuels and agrochemicals, local adaptation, the defense of biodiversity and social values or governance and participation in their management, among 13 principles described and related to the 10 elements of FAO.

Agroecology in its different dimensions encompasses the application of ecological principles to agriculture, by increasing farm diversification [20], eliminating of chemical inputs [21], increasing biodiversity in all its aspects [22], contributing to the improvement of soil biological fertility, addressing the relationships and interactions between organisms and their environment [23], managing agricultural ecosystems, including the food system in general, not only primary production, but also supply and distribution chains, food processing, marketing and food consumption [17]. Many of these dimensions already have defined and quantifiable indicators, and theoretically all these agroecological principles contribute differently, directly or indirectly, to food security and nutrition, but in reality, there are no defined indicators to assess nutritional quality and its impact on human health and well-being, in exclusive relation to agroecological principles.

The most current scientific evidence [24-27] concludes that the global food system is causing malnutrition, environmental degradation with loss of biodiversity and direct impacts on climate change, therefore a deep transformation of the prevailing food system towards more sustainable food systems is increasingly needed, considering agroecology, as the viable potential for food management and production and human well-being.

This study aims to establish a proposal for quantifiable, easily measurable indicators that allow the direct incidence of food and nutritional quality to be evaluated in order to respond to the demand for an integrated evaluation of agroecological systems, thus improving the tools for the calculation of current indicators. The global premise is that the proposed nutritional quality indices should contribute to the calculation of a food model sustainability index and to the development of methodologies that combine agroecological and socioeconomic indicators.

Methods

In the first phase, the methodology used consisted of a search for existing frameworks and indicators for the evaluation of agroecological approaches. This scientific basis was complemented by discussions at various expert workshops. The workshops were conducted during the months of April-July 2020 by the Spanish Society of Organic Agriculture [28] in online format. The values of different stakeholders (farmers, scientists, technicians, consumers, political agents, etc.) in the field of agroecology are collected. In the second phase, the results have been related to work on the set of indicators proposed by FAO, to fill some existing gaps in the area of food sovereignty and security and especially of indicators related by human welfare.

The measurement scale for each indicator is from 0 to 5, according to the writing skill classification [29], with 0 being the value least close to the agroecological criterion and 5 the closest. The total score for each parameter, divided by its indicators number, provides an overview of each parameter. The numerical value of each parameter can be represented in a diagram, e.g. a radar-type, to visualize the comprehensive analytical approach. These diagrams will make it possible to compare different models or agri-food systems and their influence on human well-being, and even to study the temporal evolution of the same system.

Results

The proposal presented is a consolidated set of ten parameters to quantify food security and sovereignty and their relationships with nutrition and human well-being. Each of these parameters is divided into a series of measurable indicators, which are those that qualitatively and quantitatively define the parameter. Each parameter is the combination of several indicators, as some of the proposed indicators may or may not be significant, or they may or may not be measurable.

The proposed parameters cover aspects that have a greater or lesser impact on the daily diet, such as the food variability that make up the dish, their contribution to food safety, the nutritional composition and bioactive components, organoleptic aspects, degree of processing and transformation of the food consumed and

environmental aspects. As well as parameters of the social sphere, such as the impact on the economy of scale, on attributes of proximity, temporality, as well as indicators related to social justice. With all of them it is intended to broaden holistic definition of agroecology, especially of those aspects that affect food security, nutrition and human well-being.

Results

Availability of basic and diverse foods that contribute to increase the diversity

The development of agriculture and the domestication of animals has entailed risks to the decrease in biological diversity and the proper functioning of agroecosystems. Effects that are more visible depending on the type of agriculture and livestock. Large-scale farming implies a greater simplification of the environmental structure, reducing biotic species and replacing innate biodiversity and the landscape with a reduced number of cultivated plants and domesticated animals. In some cases, this implies irreversible effects on the biodiversity of the system.

Agroecology promotes the use of local biodiversity, including traditional foods from indigenous and local ecosystems with their many sources of quality, nutrient-rich, easily accessible, locally empowering and sustainable species and varieties.

Preserve biodiversity, including that related to culture and food and gastronomic traditions, the use of genetic resources, livestock, forest-based foods, and aquatic genetic resources, and avoid excessive hunting/fishing [30]. By promoting a diverse and varied diet, farm diversity increases. The healthy nutrition guidelines [31] propose that approximately 50% of the diet includes fruits and vegetables, 25% whole grains, and the remaining 25% protein (including legumes), fats and dairy products. The best way to meet these guidelines is to increase the number of variable foods per ration, to be consumed.

The proposed measurable indicators for this parameter in the daily diet are as follows: *i*) variable portions of food that make up the dish; *ii*) portions of native varieties and breeds and *iii*) contribution of the daily diet to cultural and gastronomic diversity. Table 1 shows the descriptive scales to quantify the contribution to diversity and diverse diet.

Table 1. Indicators characterization in varied and diverse diet

	Score					
Index	**0**	**1**	**2**	**3**	**4**	**5**
Variable portions of food	One or two ingredients in the main meal	Three to five ingredients in the main meal	Five ingredients without reaching 50% of fruits and vegetables	Five ingredients reaching 50% of fruits and vegetables	Meet the variability criteria of the healthy guidelines	Exceed the variability criteria of the healthy guidelines
Portions of native varieties and breeds in the meal	No indigenous varieties or breeds	5% indigenous varieties or breeds	10% indigenous varieties or breeds	15% indigenous varieties or breeds	20% indigenous varieties or breeds	More 20% indigenous varieties or breeds
Cultural and gastronomic diversity	Does not include traditional recipes	5% include traditional recipes	10% include traditional recipes	15% include traditional recipes	20% include traditional recipes	More 20% recipes are from the local gastronomy and contribute to the maintenance of culture

Contribution to food safety

Modern epidemiology relates pandemic processes not only to isolated microbiological elements [32], but to others closely related to the food production system. It is within this framework, that agroecology is more necessary than ever, since it addresses the agrarian systems and food transformation in a broad context that includes ecological variables that can contribute to define the principles of food safety and security.

In organic farming, no synthetic agricultural or livestock inputs are used, such as pesticides, herbicides, fertilizers, fungicides, veterinary drugs (antibiotics, growth hormones, etc.), neither synthetic preservatives nor additives. Food cannot be irradiated and genetic organisms modified (GMO) are not authorized. This avoids, as far as possible, the potential hazards posed by

residues of synthetic inputs. In addition, organic foods are microbiologically safe and do not present a risk of disease transmission associated with pathogens [33]. The proposed measurable indicators for this parameter in the daily diet are: *i*) presence of drugs or their metabolites; *ii*) use of chemical additives; *iii*) presence of pesticide residues; *iv*) presence of GMO; *v*) presence of nitrites and nitrates; *vi*) presence of heavy metals and *vii*) microbiological presence. Table 2 shows the descriptive scales to quantify the contribution to food safety.

Table 2. Indicators characterization in food safety

	Score					
Index	0	1	2	3	4	5
Drugs or their metabolites	Presence in concentrations harmful to all people	Presence in concentrations harmful to children	Presence in concentrations harmful to women	Presence in concentrations harmful to men	Signs of absence	Demonstrable absence
Use of alimentary additives	Demonstrable presence	Signs of presence			Signs of absence	Demonstrable absence
Pesticide residues	Presence in concentrations harmful to all people	Presence in concentrations harmful to children	Presence in concentrations harmful to women	Presence in concentrations harmful to men	Signs of absence	Demonstrable absence
GMO	Demonstrable presence	Signs of presence			Signs of absence	Demonstrable absence
Nitrites and nitrates	Presence in concentrations harmful to all people	Presence in concentrations harmful to children	Presence in concentrations harmful to women	Presence in concentrations harmful to men	Signs of absence	Demonstrable absence
Heavy metals	Presence in concentrations harmful to all people	Presence in concentrations harmful to children	Presence in concentrations harmful to women	Presence in concentrations harmful to men	Signs of absence	Demonstrable absence
Food microbiology	Presence in concentrations harmful to all people	Presence in concentrations harmful to children	Presence in concentrations harmful to women	Presence in concentrations harmful to men	Signs of absence	Demonstrable absence

Contribution to nutritional composition of food

The bromatological value of food is variable and depends on different factors, including techniques (genetic potential of the plant or livestock product), as well as the rest of the factors involved in the production system (fertilization, phytosanitary products, irrigation water, exposure to light, livestock feeding, animal welfare, prophylaxis, ...). In addition, the different methods and products used in post-harvest and elaboration process can be decisive for the final composition and quality of the food [34]. Reliable data on the nutritional composition of foods are becoming essential for the formulation of appropriate therapeutic diets to remedy population deficiencies of essential nutrients.

The proposed measurable indicators for the contribution to nutritional composition of food in the daily diet are: *i*) Dietary energy supply; *ii*) quality of the lipid profile of fat; *iii*) contribution and quality of protein; *iv*) fiber intake; *v*) vitamin intake; *vi*) mineral intake. Table 3 shows the descriptive scales to quantify the contribution to nutritional composition of food.

Contribution of bioactive components to the diet

Bioactive compounds are essential and non-essential compounds (e.g., vitamins or polyphenols) that are part of the food, are present in nature, and provide health benefits beyond the basic nutritional value of the food. Bioactive compounds are also referred to as antioxidants and nutraceuticals, a term that reflects their existence in the human diet and their biological activity [35]. Concerning the organic food, research show that higher levels of antioxidants have been found [36], possibly due to the higher stress suffered by plants in the organic system.

Some studies propose color as a tool to evaluate the presence of bioactive compounds in food products [37]. Sulfur aroma is another indicator of the presence of bioactive compounds.

Table 3. Indicators characterization to contribute to the nutritional composition of food

	Score					
Index	0	1	2	3	4	5
Dietary energy supply	Deficit contribution/ Excessive contribution	Deficit between 50-40% of caloric intake	Deficit between 40-30% of caloric intake	Deficit between 30-20% of caloric intake	Deficit between 20-10% of caloric intake	Balanced contribution according to age, physical activity and others questions
Quality of the lipid profile of fat	Deficit contribution/ Excessive contribution	Between 100-90% of fat consumption is saturated fatty acids	Between 90-60% of fat consumption is saturated fatty acids	Between 60-30% of fat consumption is saturated fatty acids	Between 30-10% of fat consumption is saturated fatty acids	Adequate ratios of fatty acids ω3, ω6 and ω9.
Contribution and quality of protein	Deficit contribution/ Excessive contribution	20% of the protein is of high biological value	40% of the protein is of high biological value	60% of the protein is of high biological value	80% of the protein is of high biological value	100% of the protein is of high biological value
Fiber intake	Deficit contribution	20% consumption according to the recommendations	40% consumption according to the recommendations	60% consumption according to the recommendations	80% consumption according to the recommendations	Consumption according to the recommendations
Vitamin intake	Deficit contribution	20% levels that meet the recommended daily doses	40% levels that meet the recommended daily doses	60% levels that meet the recommended daily doses	80% levels that meet the recommended daily doses	Levels that meet the recommended daily doses
Mineral intake	Deficit contribution	20% levels that meet the recommended daily doses	40% levels that meet the recommended daily doses	60% levels that meet the recommended daily doses	80% levels that meet the recommended daily doses	Levels that meet the recommended daily doses

The proposed measurable indicators for the contribution of bioactive components of the daily diet are: i) contribution in chlorophylls; ii) contribution in carotenoids; iii) contribution in polyphenols; iv) contribution to sulfur compounds, glycosylates, and organosulfur compounds. Table 4 shows the descriptive scales to quantify the contribution to bioactive components of food.

Table 4. Indicators characterization to the contribution of the bioactive components of food

	Score					
Index	0	1	2	3	4	5
Contribution in chlorophylls	No green foods	1 serving of green foods	2 serving of green foods	3 serving of green foods	4 serving of green foods	5 serving of green foods
Contribution in carotenoids	No yellow, orange or red foods	1 serving of yellow, orange or red foods	2 serving of yellow, orange or red foods	3 serving of yellow, orange or red foods	4 serving of yellow, orange or red foods	5 serving of yellow, orange or red foods
Contribution in polyphenols	No purple foods	1 serving of purple foods	2 serving of purple foods	3 serving of purple foods	4 serving of purple foods	5 serving of purple foods
Contribution in sulfur compounds	Not smell of sulfur foods	1 serving of foods with sulfur aromas	1 serving of foods with sulfur aromas	2 serving of foods with sulfur aromas	2 serving of foods with sulfur aromas	3 serving of foods with sulfur aromas

Contribution to organoleptic attributes by food in the diet

The smell, color, taste and texture are properties that strongly influence the acceptance or rejection of food by consumers. The sensory or organoleptic evaluation analyzes and interprets the reactions caused by these attributes or characteristics of the food. The perception of a sensory attribute involves information gathered by the senses, the physiology itself and the experiences that have shaped motivations and expectations. The taste is formed as a result of the interaction between taste and smell properties. It is one of the most important factors influencing food preference. Appearance and smell appear to be the most important sensory attributes when consumers buy food, while taste and aroma are the most important attributes when consumers taste a food. This implies that consumers differ between their perception of sensory attributes and their valuation in relation to specific foods. Among the most influential attributes for the acceptance of organic foods are the preference for natural flavor, the sensation of less sweetness, foods with more intense aroma, whole foods, preference for fresh foods, and preference to be obtained by traditional methods when they are transformed [38]. In general, the sensory attributes of agroecological foods are superior [39], or they are not of worse organoleptic quality [40].

The proposed measurable indicators for the contribution to the sensory attributes of the daily diet are: i) natural aroma recognition; ii) natural flavor recognition; iii) natural texture recognition; iv) the emotions evoked by food. Table 5 shows the descriptive scales to quantify the contribution to the sensory attributes of food.

Table 5. Indicators characterization to contribution at sensory attributes of food

	Score					
Index	0	1	2	3	4	5
Natural Aroma	Not natural aroma	20% of food shows its natural aroma	40% of food shows its natural aroma	60% of food shows its natural aroma	80% of food shows its natural aroma	100% of food shows its natural aroma
Natural flavor	Not natural flavor	20% of food shows its natural flavor	40% of food shows its natural flavor	60% of food shows its natural flavor	80% of food shows its natural flavor	100% of food shows its natural flavor
Natural texture	Not natural texture	20% of food shows its natural texture	40% of food shows its natural texture	60% of food shows its natural texture	80% of food shows its natural texture	100% of food shows its natural texture
The positive emotions evoked by food (childhood memories or similar)	Not evoke positive emotion	20% of food evoke positive emotions	40% of food evoke positive emotions	60% of food evoke positive emotions	80% of food evoke positive emotions	100% of food evoke positive emotions

Impact on the level of food processing

Food processing is closely linked to anthropological aspects of human evolution. Since the domestication of fire, humans have treated food with the basic objective of preserving its nutritional and organoleptic properties, in addition to eliminating/reducing biological risks, obtaining a microbiologically safe food and increasing shelf life. Public health policies have led to the emergence of different food classification systems according to their degree of processing. Among the different food classification systems based on the degree of processing is the NOVA system [41], which is used in most studies to analyze and document the effect of ultra-processed food consumption on various diseases or markers of disease, health or mortality. NOVA system describes four groups, natural and minimally processed, processed culinary ingredients, processed foods, and ultra-processed food (food that can hardly be recognized in their original state). The proposed measurable indicators for the impact on the level of food processing of the daily diet are: i) natural diet or with minimally processed foods, including commonly used culinary ingredients, with little modification of the original structure of the food. Boiled, filtered, ground, powdered, squeezed food; ii) diet that includes processed foods, includes processed foods with added salt, sugar and fat; iii) diet that includes ultra-processed foods, which have lost the original structure of the food and are formulated with ultra-processed ingredients and with a very high

number of additives. Table 6 shows the descriptive scales to quantify the contribution to level of food processing.

Table 6. Indicators characterization to contribution at level of food processing in the daily diet

	Score					
Index	0	1	2	3	4	5
Natural diet or with minimally processed foods	Lower 10% of diet is minimally processed	10-20% of diet is minimally processed	20-40% of diet is minimally processed	40-60% of diet is minimally processed	60-80% of diet is minimally processed	More 80% of diet is minimally processed
Diet that includes processed foods	More 80% of diet is processed	60-80% of diet is processed	40-60% of diet is processed	20-40% of diet is processed	10-20% of diet is processed	Lower 10% of diet include processed
Diet that includes ultra-processed foods	More 80% of diet is ultra-processed	60-80% of diet is ultra-processed	40-60% of diet is ultra-processed	20-40% of diet is ultra-processed	10-20% of diet is ultra-processed	Lower 10% of diet include ultra-processed

Contribution to reduce the environmental impact, with special contribution to carbon and water footprint by the diet

Globally, agriculture uses about 70% of all freshwater with-drawls for irrigation, although there are discrepancies exist in the quantified amount [42], with most irrigation concentrated in densely populated developing countries. The consumption of water from crops, green water (evapotranspiration stemming from precipitation on crop-land) and blue water (evapotranspiration on cropland stemming from irrigation) has increased with the extension of agricultural land, and particularly irrigated areas. The use of blue irrigation water is in direct competition with the use of water by households and industry. The proposed measurable indicators for the contribution to reduce the environmental impact, with particular contribution to carbon and water footprint of the diet are: i) energy use; ii) type of energy; iii) use of packaging; iv) water consumption in agri-food system; v) closure of cycles and recovery of inputs. Table 7 shows the descriptive scales to quantify the contribution to the reduction of environmental impact.

Table 7. Indicators characterization for the contribution to the reduction of environmental impact, with special contribution to the carbon and water footprint of the diet

	Score					
Index	0	1	2	3	4	5
Energy use	More 80% of the diet depend on fossil energy in production, cold chain, transport and others	60-80% of the diet depend on fossil energy in production, cold chain, transport and others	40-60% of the diet depend on fossil energy in production, cold chain, transport and others	20-40% of the diet depend on fossil energy in production, cold chain, transport and others	10-20% of the diet depend on fossil energy in production, cold chain, transport and others	Lower 10% of the diet depend on fossil energy in production, cold chain, transport and others
Type of energy	Lower 20% of energy comes from non-fossil sources	20% of energy comes from non-fossil sources	40% of energy comes from non-fossil sources	60% of energy comes from non-fossil sources	80% of energy comes from non-fossil sources	100% of energy comes from non-fossil sources
Use of packaging	More 80% of the food is packaged	60-80% of the food is packaged	40-60% of the food is packaged	20-40% of the food is packaged	10-20% of the food is packaged	Lower 10% of the food is packaged
Water in agro-food system	More 80% comes from blue water	60-80% comes from blue water	40-60% comes from blue water	20-40% comes from blue water	10-20% comes from blue water	Lower 10% comes from blue water
Closure of cycles and recovery of inputs	Lower 10% of waste is recycled	10-20% of waste is recycled	20-40% of waste is recycled	40-60% of waste is recycled	60-80% of waste is recycled	More 80% of waste is recycled

The idea of food system circular implies that the value and utility of products are increased and that waste from production and consumption is used as secondary resources, promising solutions and co-benefits to a range of economic and environmental problems [43]. The food system must be kept within environmental limits and agroecology can be an alternative to establish the necessary balance between food production and environmental impact.

Contribution to the economy of scale with the daily diet

The often-unequal power relations between smaller and bigger players in the global food supply chain generate significant tensions. Small scale agricultural production and consumption that support local products are being overshadowed worldwide [44]. At the local level, it means that the quantity and the demand are declining, as is the diversity of products, leading to the gradual disappearance of local characteristics, traditional knowledge and confidence. Small farms face serious challenges that make their future precarious. The danger for many small farms is that they are not yet in a position to compete and access global markets and many will simply be left behind. In developing countries, smallholder farmers also face unfair competition from farmers in richer countries in many of their domestic and international markets.

Short food supply chains, which promote agroecology, offer a solution to these problems

They reduce the physical distance between producers and customers, give small farmers opportunities to produce and sell high-quality local goods directly and facilitate consumer access. Agroecological approaches promote fair solutions based on local needs, resources and capacities, creating more equitable and sustainable markets. For this reason, agroecology seeks to reconnect producers and consumers through a solidarity and economy of scale that prioritizes local markets and supports the local economy [45]. The proposed measurable indicators for the contribution of the diet to the economy of scale are: *i*) marketing system; *ii*) co-responsibility and community cooperation; *iii*) fair trade; *iv)* food sovereignty. Table 8 shows the descriptive scales to quantify the contribution of the diet to the economy of scale.

Table 8. Indicators characterization to contribution at the economy of scale by the diet

	Score					
Index	0	1	2	3	4	5
Marketing system	Lower 10% food comes from direct or local farmers markets or cooperative models	10-20% food comes from direct or local farmers markets or cooperative models	20-40% food comes from direct or local farmers markets or cooperative models	40-60% food comes from direct or local farmers markets or cooperative models	60-80% food comes from direct or local farmers markets or cooperative models	More 80% food comes from direct or local farmers markets or cooperative models
Co-responsibility, community cooperation	No participation in cooperative work, consumer training, etc.	Participation of 2 h/month in cooperative work, consumer training, etc.	Participation of 3 h/month in cooperative work, consumer training, etc.	Participation of 4 h/month in cooperative work, consumer training, etc.	Participation of 5 h/month in cooperative work, consumer training, etc.	Participation of more 6 h/month in cooperative work, consumer training, etc.
Fair trade	Lower 10% of food comes from fair trade	10-20% of food comes from fair trade	20-40% of food comes from fair trade	40-60% of food comes from fair trade	60-80% of food comes from fair trade	More 80% of food comes from fair trade
Food sovereignty and responsible governance	Lower 10% of consumption model contributes to food sovereignty	10-20% of consumption model contributes to food sovereignty	20-40% of consumption model contributes to food sovereignty	40-60% of consumption model contributes to food sovereignty	60-80% of consumption model contributes to food sovereignty	More 80% of consumption model contributes to food sovereignty

Contribution to the rationality of the consumption model with the daily diet

Irrational farming systems lead to a series of injustices for farmers and consumers. The pressure to provide out-of-season food forces local farmers to grow food in

greenhouses, which may require as much or more energy than transporting it from areas with more favorable climates. Small-scale marketing venues are becoming increasingly scarce, and the prices of local products cannot compete with the low-cost of imported products due to the kilometer-long agri-food system. Out-of-season food production, transport and marketing causes a great socio-environmental impact. In addition, the use of fossil fuels is necessary, with significant expense both at the points of processing, packaging, storage and distribution before reaching consumers.

Local and seasonal agroecological food establishes a fundamental relationship with local farmers and with points of sale that favor economies of scale and sustainable and local agriculture [46]. On the other hand, the link with the territory is not only productive, but is also related to the support of cultural strategies, traditional systems, ecosystem services, bartering, etc. The proposed measurable indicators for the contribution to the rationality of the consumption model with the daily diet are: i) temporality; ii) proximity; iii) territorial personality. Table 9 shows the descriptive scales to quantify the contribution to the rationality of the consumption model with the daily diet.

Table 9. Indicators characterization to contribution at the rationality of the consumption model with the daily diet

	Score					
Index	0	1	2	3	4	5
Temporality	Lower 10% food is seasonal	10-20% food is seasonal	20-40% food is seasonal	40-60% food is seasonal	60-80% food is seasonal	More 80% food is seasonal
Proximity	Lower 10% food comes from less than 100 km	10-20% food comes from less than 100 km	20-40% food comes from less than 100 km	40-60% food comes from less than 100 km	60-80% food comes from less than 100 km	More 80% food comes from less than 100 km
Territorial personality	Lower 10% of consumption model contributes to development of territory	10-20% of consumption model contributes to development of territory	20-40% of consumption model contributes to development of territory	40-60% of consumption model contributes to development of territory	60-80% of consumption model contributes to development of territory	More 80% of consumption model contributes to development of territory

Contribution to commitment and social justice with the daily diet

Social injustice and inequality range from the realm of international policies to the household level, training centers and the other institutions of society. Social injustice cuts across the intersectional dimensions of gender, age, class and caste, religion, health, rural and urban areas and poses a major obstacle to the development of sustainable food systems [47]. Agroecology is developed in social aspects related to human well-being and addressing aspects of equity, such as the networking and community self-organization. Specifically, gender inequality is a critical barrier in agroecological transformations. Women generally have less access to land and other productive resources and decision-making, while they remain disproportionately responsible for household chores and the care of agricultural practices, such as seed guardians or food processors. Finally, agroecology is directly aligned with healthy and sustainable food and therefore with the SDGs of the 2030 agenda.

The proposed measurable indicators for the contribution to commitment and social justice with the daily diet are: *i*) decrease in food waste; ii) impact on the SDGs; iii) gender equity; iv) access to land; v) generational change; vi) quality of life of producers.

Table 10 shows the descriptive scales to quantify the contribution to commitment and social justice with the daily diet.

Table 10. Indicators characterization for contribution to commitment and social justice with the daily diet

	Score					
Index	0	1	2	3	4	5
Decrease in food waste	There is 25% food waste	There is 20% food waste	There is 15% food waste	There is 10% food waste	There is 5% food waste	No food waste
Impact on the SDGs	Alignment with less 6 SDGs	Alignment with 6 SDGs	Alignment with 9 SDGs	Alignment with 11 SDGs	Alignment with 14 SDGs	Alignment with the 17 SDGs
Gender equity	Gender equity is decreased in governing bodies	Gender equity is decreased in governing bodies	Gender equity is equated in governing bodies	Gender equity is equated in governing bodies	Gender equity is exceeded in governing bodies	Gender equity is exceeded in governing bodies
Access to land	Contrary to land access policies	Contrary to land access policies	It does not influence land access policies	It does not influence land access policies	In accordance with land access policies	In accordance with land access policies
Generational change	No intergenerational activities and young farmers	No intergenerational activities and young farmers	Incorporation of young farmers	Incorporation of young farmers	Intergenerational activities and young farmers are carried out	Intergenerational activities and young farmers are carried out
Quality of life of producers	Food income affects less than 50% on producers and their quality of life	Food income has a 50% impact on producers and their quality of life	Food income has a 60% impact on producers and their quality of life	Food income has a 80% impact on producers and their quality of life	Food income has a 90% impact on producers and their quality of life	Food income has a 100% impact on producers and their quality of life

Discussion

The diet pattern is the dominant driver of the planet's growing environmental footprint and its effects on climate change. Global food consumption has undergone a rapid increase and a major structure transition as a consequence of population growth and economic development. The food system is increasingly threatening the environment by depleting water resources, degrading water bodies, aggravating climate change, degrading ecosystems, etc. The environmental impacts of food can be reduced through relations between producers and consumers [48].

Food production, commercialization, composition, transformation and consumption of food, social and cultural factors, and the health of people in rural and urban areas, are descriptive components of any agri-food system, with an impact on human well-being. In an increasingly global, urban and commercial environment, harnessing the potential of local resources, through local, seasonal and proximity production are essential factors in defining the sustainability of the food system.

The most recent evidences conclude that the world food system is not providing good nutrition to people and is leading to environmental degradation and loss of biodiversity. It is therefore necessary to generate an intense agri-food transition to face the challenges of constant malnutrition and rural poverty, aggravated by the growing consequences of climate change. Recently, agroecological food experiences have multiplied around the world. These experiences constitute important innovation niches for a new and more sustainable diet [49]. They generate greater social equity in terms of prices at origin and destination [50]. Agroecology is the effective tool to transform the agri-food system in depth. Thus, agroecological practices can regenerate the soil, protect water, promote biodiversity, and mitigate the effects of climate change. But it also brings benefits in terms of human well-being, through parameters of social, cultural, health, employment, gender equality, generational renewal and revitalization of the rural world.

Given the importance of diet, as a determinant of good health, and the need to prevent the main chronic diseases related to nutrition, it is necessary that agroecology as a science sensitive to nutrition, sustainable production and consumption of food, be in line with the dietary guidelines, contributing to its holistic character. In this sense, the present study proposes to measure the dietary diversity by quantifying three indicators, which assess the

plurality of foods that make up the daily intake, the incorporation of native varieties and breeds, and the gastronomy associated with the territory. The greatest dietary diversity is achieved by increasing the intake of fruits and vegetables, since the intake of vegetable protein is more diverse. The increased consumption of fruits and vegetables is in line with the Harvard Plate Dietary Guidelines, where 50% of the meal configuration should be fruits and vegetables. This is achieved with a diverse configuration of the dish, fun in colors, textures and flavors, to make the meal a pleasant moment.

Generating the need to consume traditional dishes, made with native varieties, enhances the demand for varied crops in the area, contributing to the increase of cultivated genetic diversity reducing the loss of biodiversity. Traditional cultivars have been grown for a long time (>50 years), and have a heritage that has been preserved by regional, ethnic, or family groups. Heirloom cultivars also are closely associated with organic and sustainable farming systems, and generally perform much better under these conditions than in modern, industrialized farming systems [51]. This brings us to the second, third and fourth contributions of indicators, related to food safety and nutritional composition, and the need to build clean food systems free of chemical loads, with nutritionally balanced foods that have an impact on good health. Currently, natural food is one of the most demanded products and this partly overlaps with their perception of organic food [52]. Some authors have established criteria to quantify the degree of nutritional quality [53] and comprehensively conceptualize the naturalness of foods [54], but these metric evaluations do not contemplate the agroecological dimension of food.

Food preferences can change over time, and the nutritional transition from traditional diets to diets rich in meat, refined sugars and saturated fat is a clear example of significant changes that occur in a short period of time. Dietary transition is highly influenced by the organoleptic attributes of food, but specific emotions have also been considered determinants of consumption responses and can predict the individual's food choices more accurately than taste scores. Assessment of emotional responses to organic foods may reveal previously unknown product attributes that can be a valuable source of information and go beyond traditional sensory and acceptability measures. Therefore, it is important to obtain valid and reliable combinations of measurements of sensory attributes and emotions evoked by food and developed in the fifth group of indicators.

The food consumed by a certain group conveys a cultural meaning about the social hierarchy, social systems and the relationships between human and the environment. As Springmann [48] suggests, per capita food emissions translate into different diets, according to regional contexts, including cultural and gender norms. Alliances between farmers and consumers must be strengthened through agroecology. The information will make it possible to make an appropriate choice of food, linked to a specific origin, produced in a sustainable way and capable of generating human well-being. On the one hand, consumers must be informed about the nature, origin and composition of food and the impact of food systems. On the other hand, farmers should also have more flexible market structures, allowing small farmers to have physical and/or virtual spaces for the commercialization of their food, without intermediaries, complying with the proximity that ensures a solid structure of the base economy.

Agroecology based on short food supply chains is an initiative that allows small farmers to have greater visibility in local markets, better control the prices of their products and be more independent with respect to what they produce, as well as better relationships with their clients [55]. These direct and trusting relationships with consumers contribute to reducing the metabolic profile of food systems by reducing energy consumption through the promotion of short distribution channels, increasing consumption of fresh and seasonal food and using less packaging and additives, to preserve food [56].

Attending farmers markets or buying directly from local producers has been shown to change worldviews [57] and eating habits towards healthier diets [58]. The physical proximity of the food makes it possible to purchase more frequently and acquire smaller volumes per occasion, adjusted to needs, avoiding waste. Physical proximity also means that fossil resources do not have to be spent for transportation to sales areas.

Agroecology focused on small producers ensures that they have a fair income. The establishment of appropriate links between farm labor and the area of management that can be executed, this guarantees a greater incorporation of farmers to the primary sector, with degrees of training and knowledge exchange between similar, but also intergenerational, cropping is valued as an enveloping factor in agricultural activity. These aspects of the food system are quantified in the different indicators of the other categories. All the proposed parameters and

indicators are very much in line with the sustainable development goals. The 17 SDGs and their 169 targets largely coincide with the determinations of agroecological nutrition and the quantification criteria expressed in this paper, picking up the interaction of economies of scale, social, environmental and human well-being aspects. Agroecology is not viable without linear and reciprocal cooperation between responsible production, distribution, logistics and consumption [59]. In this cooperation, each link in the food chain is a product of the previous links and a premise for the followings. In the case of the SDGs, both the Goals that favor agroecological nutrition and those that favor it, are integral and cross-cutting nature, so the indicators proposed in this study could be used to assess the degree of compliance of some Goals.

Conclusions

A list of ten consolidated parameters with quantifiable indicators is elaborated and discussed, in the context of food systems evaluations, based on holistic aspects affecting food security, nutrition and human well-being.
For a diet to be healthy, it must be good for people, for soil, water and for any other resource on the planet, therefore it must be varied and mainly vegetable, seasonal, local, socially fair, accessible through a short marketing channel, nutritionally balanced, free from health risks, with beneficial substances contribution and with a high impact on environmental, cultivated, gastronomic and cultural biodiversity.

Agroecology should help to recover the gastronomic cultural heritage against the food standardization, recovering local biodiversity and its use in cooking and offering healthy, tasty and pleasant food. Agroecology is an engine of change and a solution agent for the entire agri-food system. It is necessary to understand food as a right and not as a business, i.e. a shift towards agri-ecological models, that allow proper management of agriculture, livestock, forestry and aquaculture, and that the result of good productive management is to offer nutritious food to all people, as well as a decent income to producers, supporting the sustainable development of the rural model, environmental protection, food security, good nutrition and human well-being. A sustainable lifestyle is essential for the population to achieve human well-being and the way to reach this goal is through the agroecological transition of the global food system.

The proposal should provide an evaluation tool before or after the implementation of agricultural policies towards agroecological transition; a form of self-assessment, internally managed and repeated after a certain period or after a change in agricultural when redesigning or introducing diversity strategies. It would also be useful as a consumer choice guide for buying. Finally, it can also be used to assess the degree of compliance with the SDGs, especially those related to food.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of view and not that of the institution to which they belong.

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Reflection Research Article

Agricultural and Biological Sciences

Unraveling mosaic viruses in contemporary agriculture: In-depth insights on characterization, impact, diagnosis, treatment, and management

Desentrañando los virus mosaico en la agricultura moderna: Perspectivas profundas sobre la caracterización, impacto, diagnóstico, tratamiento y manejo

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Abstract

Mosaic viruses are a constant concern for the agricultural sector. They pose a real threat to both food and ornamental crops, causing huge economic losses and even threatening food security in many regions. In this article, we will present a general overview of these viruses: their characteristics, transmission mechanisms, effects on crops and available control methods. We will see that one of the main difficulties in dealing with mosaic viruses is their diversity and wide host range. In addition, the lack of effective treatment alternatives and the practical challenges of diagnosing different mosaic virus species require constant epidemiological vigilance to prevent their spread. We will first present a general characterisation of mosaic viruses as an informal group of viruses belonging to tens of different taxa. We will then review the main symptoms of mosaic virus infection (hence the name "mosaic"), diagnostic methods, host range, transmission mechanisms and treatment options. Secondly, we will discuss the impact of these viruses on ornamental and food crops. Finally, we will look at some possible strategies for infection management and control.

Resumen

Los virus mosaico son una preocupación constante para el sector agrícola. Representan una amenaza real para los cultivos, tanto alimenticios como ornamentales, y pueden llegar a generar pérdidas económicas millonarias y hasta a poner en riesgo la seguridad alimentaria en muchas regiones. En este artículo queremos presentar un panorama general de estos virus, sus características, medios de transmisión, impactos en cultivos y medios de control disponibles. Veremos que una de las dificultades fundamentales al enfrentar los virus mosaico es su diversidad y su extenso rango de posibles huéspedes. Además, la ausencia de tratamiento eficaz y los retos prácticas del diagnóstico de diferentes especies de virus exige un trabajo constante de vigilancia y seguimiento epidemiológico para evitar la propagación de virus mosaico. Empezaremos proponiendo una caracterización general de los virus mosaico como un grupo informal de virus pertenecientes a decenas de taxones diferentes. Luego veremos los síntomas característicos de una infección por virus mosaico (que le deben el nombre “mosaico”) así como los métodos de diagnóstico, el rango de huéspedes, los medios de transmisión y los posibles tratamientos. En segundo lugar, haremos una revisión del impacto de este tipo de virus en cultivos alimenticios y ornamentales. Y, por último, veremos las posibles estrategias de manejo y control de infecciones.

Introduction

Food security depends on a number of human, climatic, economic and epidemiological factors. 80% of human food comes directly from plants, not to mention their role in animal feed [1,2]. Plant and crop health must therefore be a constant concern for governments. One of the greatest current threats to the agricultural sector, and therefore to economic stability and global food security, is plant viruses. Each year, viral infections in crops are responsible for around $30 billion in losses [3,4] and more than 50% of the plant diseases in the world [5,6].

From this perspective, plant health should be a priority concern for both governments and all actors in the agricultural sector [7,8]. However, despite their importance and impact, the diagnosis, treatment and management of plant viral diseases represent a major challenge for the agricultural sector [9,10]. Some of the pathogens of greatest concern in this regard are the so-called "mosaic viruses", an informal and very diverse group of viruses with similar symptomatic characteristics that affect a wide variety of plant species [11]. Mosaic viruses cause hundreds of different plant diseases, causing millions of dollars in losses and posing a threat to food security, especially in developing countries [12,13].

Within this context, the aim of this contemplative analysis is to offer a comprehensive exposition on mosaic viruses. This entails delving into their fundamental characteristics, thoroughly assessing their substantial ramifications on crops [14] and elucidating the spectrum of accessible diagnostic and management methodologies. This endeavor seeks to unravel the intricate interplay between mosaic viruses and modern agricultural ecosystems, shedding light on their multifaceted influence and unveiling strategic pathways for effective intervention.

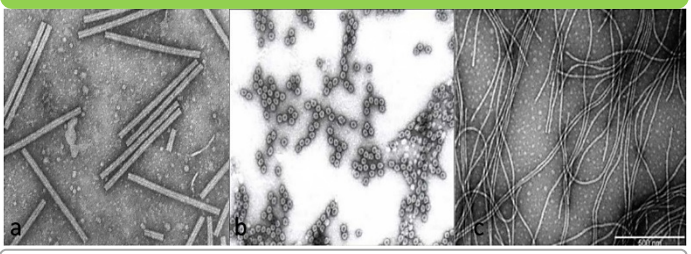
Diversity and impact of mosaic viruses

Characterisation

Mosaic viruses, although not directly related taxonomically, form a complex group of pathogens that affect a wide variety of plants with remarkably similar symptoms. The name 'mosaic' is derived from the mottled appearance of the leaves of infected plants. This viral conglomerate is defined by its manifestations and effects on crops rather than by its taxonomy per se. In fact, the term "mosaic virus" groups together about 150 viruses belonging to several different taxa.

These include single-stranded positive RNA viruses, such as those in the order Tymovirales, single-stranded negative RNA viruses, such as those in the order Bunyavirales, double-stranded DNA viruses, such as members of the family Caulimoviridae, single-stranded DNA viruses, such as those in the family Gemiviridae, and even satellite viruses, such as those in the genus Betasatellite. As a result, this category of viruses exhibits an astonishing diversity of characteristics in terms of genomic composition, virion structure, size, replication processes, propagation mechanisms and distribution patterns. The diversity of their characteristics defines a broad and complex field in which they operate, which is being addressed by several researchers [15-17] (see figure 1).

Figure 1. Diversity of virion structure in different mosaic virus species



a) Tobacco mosaic virus [18]; b) Cucumber mosaic virus [19]; c) Althernantera mosaic virus [20].

The best-studied virus in this group is probably tobacco mosaic virus (TMV), which has also played an important role in virological research [18,21]. In 1898, Martinus Beijerink first used the term "virus" to describe a pathogen infecting tobacco plants that was too small to be considered a bacterium. A few decades later, in 1935, VMT would be the first virus to be crystallised, in this case by Wendell M. Stanley - who would receive the Nobel Prize for his work in 1946. Since then, VMT, a mosaic virus, has become the model virus for research and the basic pathogen for much of the fundamental research and concepts in biology, medicine and agricultural engineering [21,22].

Today, mosaic viruses, along with other types of plant viruses, are the focus of intense research in virology, agricultural engineering and environmental studies. In fact, according to a survey of virologists, 5 of the 10 plant viruses currently considered to be of major scientific and economic importance are mosaic viruses [18]. Research

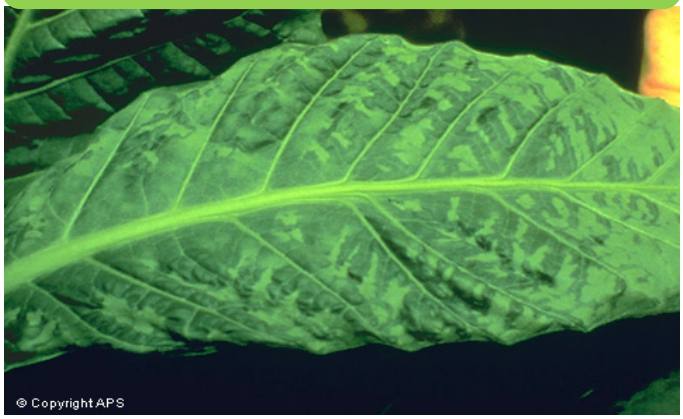
has been devoted to better understanding their transmission and infection mechanisms, finding new diagnostic methods and developing effective treatments to reduce the risk they pose to the global economy and food security [12,13].

Symptoms and diagnosis

Given the diversity of mosaic viruses, symptoms vary greatly depending on the virus and the species infected. However, this informal group was formed precisely because of the observable similarities between the different infections. In general, infected plants develop yellow, white or green interveinal spots on their leaves, often in a mosaic pattern. Other symptoms include stunted plant growth, necrosis, roughness or deformation of leaves and other tissues, epinasty (curling of leaves) and discolouration of veins [23].

Symptoms tend to be more pronounced on young leaves. While mosaic viruses are usually not lethal to the infected plant, they can severely affect its growth, reproduction, and flower and fruit production [24]. In the case of food crops or ornamentals, this obviously means economic losses or food safety risks [25] (see figure 2).

Figure 2. Mosaic pattern characteristic of tobacco mosaic virus infection [18]



Asymptomatic infections have been reported for a large number of mosaic virus species. On the other hand, not all mosaic virus infections are considered negative. In some cases, mosaic viruses do not have a significant effect on plant growth and health beyond leaf spots, and some growers tend to grow and maintain infected plants for their ornamental value. An example of this is Abutilon mosaic virus, which affects plants of the genus Abutilon [26]. The variegation of the leaves resulting from infection is one of the main attractions of this plant (see figure 3).

Figure 3. Example of variegation in *Abutilon* sp. caused by Abutilon mosaic virus [27]

In some cases, it is possible to identify the genus or type of mosaic virus infecting a plant from its symptoms: this is the case for cassava mosaic viruses [25]. However, in general, due to the similarity of symptoms between different mosaic virus species, it is not possible to identify the type of virus responsible for a particular infection based on symptoms alone. In this case, further virological analysis, e.g. using monoclonal antibodies or PCR, is necessary. Furthermore, in agricultural practice, identification of mosaic viruses on the basis of physiological characteristics is not an easy task, as infection can be confused with other problems such as over-irrigation, pest damage, nutrient deficiencies or even variegation (see figure 4).

Figure 4. Typical symptoms of the mosaic virus

a) *Monstera adansonii* infected with Dasheen mosaic virus. The characteristic mottled pattern of the mosaic virus can be seen, as well as leaf deformations; b) *Monstera adansonii* variegated [27]; c) Monstera adansonii with yellowing due to irrigation problems or nutrient deficiency [28].

Infected species

Generally, a particular type of mosaic virus is named after the first plant species in which it is discovered: "Tobacco mosaic virus was first discovered in tobacco. This does not mean, of course, that these viruses cannot infect other plants. In fact, mosaic viruses infect a wide variety of plant species, both monocots and dicots, and both ornamental and food crops. For example, VMT infects about 125 plant species in nine different families. These include both ornamental and food crops, including several species in the Solanaceae and Cucurbitaceae families [29]. Another important example is Cocombrosis mosaic virus (CMV), which can infect more than 1000 plant species, including ornamental and food crops in the Fabaceae, Asteraceae and Brassicaceae families [30].

Transmission

The vectors of virus transmission are as diverse as the mosaic viruses themselves. On the one hand, plant-to-plant transmission is common, either by direct contact or by mechanical transmission by humans during agricultural work (e.g. through infected tools). Viral particles can be transferred from one plant to another by entering through tissue surface lesions caused by insects, fungi or mechanical damage [31].

Pests are one of the most important vectors of mosaic viruses. Beetles, aphids, whiteflies and other sap-sucking insects (order Hemiptera) can be important vectors of several mosaic viruses. For example, CMV is transmitted by more than 80 species of aphids [30]. On the other hand, mites of the family Eryophidae transmit wheat streak mosaic virus infections; and certain nematodes (only in the families Longidoridae and Trichodoridae) serve as vectors for some mosaic viruses, in particular Arabis mosaic virus, which is responsible for infections in strawberry, hop, beet, celery and lettuce crops, among others [32]. Finally, there are fungal vectors. This is the case of mosaic viruses of the genus Bymovirus (such as oat mosaic virus, rice mosaic virus and some wheat mosaic viruses), which are transmitted by rust (Puccinia graminis) in the soil [33].

Vertical transmission is also possible, depending on the virus species. In the case of CMV and other mosaic viruses of the genus Tobamoviorus, a mother plant can produce virus-infected seeds [34]. In other species, evidence for vertical transmission via pollen from infected plants has been found: this is the case for cucumber green marbled mosaic virus and peach latent mosaic viroid [35]. This diversity of mosaic virus vectors, combined with highly effective infectious properties, makes mosaic viruses a growing concern. For example, VMT and other mosaic viruses of the genus Tobamovirus are among the most stable and infectious viruses known [18].

Treatment

There is no treatment for any of the mosaic viruses. Management is therefore based on prevention, the use of resistant species and general good environmental practices. In the event of infection, each infected plant must be isolated and destroyed to prevent spread. The possibility of composting plant material or reusing the same soil where an infected plant was located depends on the particular mosaic virus species, but in general it should be avoided to prevent further infection.

Impact on crops and ornamentals

Research will focus on gaining an in-depth understanding of the impact of mosaic viruses on plantations worldwide. One of the major challenges associated with the spread of these viruses is their impact on crops of vital economic and food importance. The importance of this issue is accentuated by the wide diversity of viruses and the variability of possible host organisms, resulting in a wide range of plant species susceptible to infection. These include major food crops such as alfalfa, tomato [36], potato, rice, cucumber and wheat.

The direct consequence of mosaic virus infection is the generation of plant deformities, dwarfing of plants, alteration of their natural pigmentation and abnormal formation of apical buds. These effects are clearly detrimental to the quality and quantity of agricultural production, as pointed out by Tun Suarez et al. [37]. Agriculture is affected not only in terms of yield, but also in terms of marketing and staple food supply, underlining the urgency of addressing this issue in a comprehensive manner.

The impact of mosaic viruses goes beyond food production, as they also affect ornamental horticulture. The diversity of plants used for ornamental purposes is also exposed to the damaging effects of these viruses, directly affecting the aesthetics of parks, gardens and urban green spaces. It is therefore essential to understand

the complexity of these effects in order to develop effective strategies to mitigate the economic losses and visual disruption caused by the presence of mosaic viruses in a wide range of plants, whether grown for their food or decorative value.

An example of the impact of mosaic viruses is the bean golden yellow mosaic virus. This virus affects perhaps one of the most typical and traditional foods of the American continent: beans (*Phaseolus vulgaris* L.); and has been affecting crops for more than 5 decades, causing agricultural emergencies in the region. Bean golden mosaic virus (BGMV) belongs to the genus Begomovirus (family Geminiviridae). It first appeared in Brazil in 1965 and spread with the rapid expansion of soybean cultivation. Although most soybean (*Glycine max* (L.) Merr.) varieties are not susceptible to Golden Yellow Mosaic Virus, this crop is a host to the whitefly (*Bemisia tabaci*), the main vector for the spread of the virus [38]. In this way, the virus spread rapidly in regions of Bolivia and Argentina, causing losses of more than 50% and severely damaging the capacity of the agricultural sector and even the ability of families to feed themselves [39] (see figure 5).

Figure 5. Symptoms of bean mosaic virus on bean plants [38]

Another very important crop in the family food basket, as well as in the agricultural and industrial sector, that has been severely affected by various mosaic virus species is maize. Maize is the third most important crop in the world and is host to around 50 virus species, including maize mosaic virus (MMV), sorghum mosaic virus (SrMV), sugarcane mosaic virus (SCMV) and maize dwarfing mosaic virus (MDMV). SCMV and MDMV in particular have a global distribution and are responsible for epidemic outbreaks and major economic losses. Both belong to the Potyviridae family and are mainly transmitted by aphids. Since the 1960s, MDMV alone has been responsible for losses of up to 70% in maize crops worldwide. MCSV affects not only maize but also the world's largest agricultural crop, sugar cane. Its distribution is global and has threatened the very continuity of the sugar cane industry in countries such as the United States, Argentina and Australia [40,41].

Another very clear example of chain infection is tomato mosaic virus, itself a member of the Tobamovirus genus, which can invade both the skin and even the embryo or internal seed tissue. This pathogen is widespread throughout the world and causes damage to tomato crops, both in greenhouses and outdoors, as well as to other Solanaceae crops. This type of virus causes negative results in yield and total plant loss. The extent of damage depends largely on the presence of soil already contaminated with the virus strain, high temperatures, high levels of inert gases such as nitrogen, and even light intensity [42].

Ornamental crops, which make up a large part of the agricultural market in countries such as Colombia, are no strangers to these viruses. In this case, one of the most important pathogens is tulip streak virus (TBV), also known as lily mosaic virus. Infections with this virus affect physical characteristics such as leaf cell deterioration, chlorosis, leaf discolouration, leaf shrinkage, necrosis and leaf deformation. TBV is mainly transmitted by aphids and affects a wide range of bulb flowers, causing economic losses in the millions, especially in Europe [43]. CMV is another virus affecting ornamental crops, including *Alstroemeria* spp. species, *Dendrobium, Galdiolus, Iris* spp., *Lilium* spp., *Dianthus* spp.

While the global economic impact of mosaic viruses is difficult to estimate (due to under-reporting and under-diagnosis), it is clear that they cause major losses to the entire agricultural sector, both in food and ornamental crops. Viruses such as MDMV, SCMV or wheat streak mosaic virus (WSMV) can affect up to 75-80% of crops, and economic losses can run into billions of dollars (e.g. losses of between $1.2 and $2.5 billion annually due to cassava mosaic virus in Africa) [3]. Mosaic viruses therefore pose a risk not only to agricultural economies but also to food security in many regions of the world, particularly in developing countries [12,13]. This highlights the importance of early detection and

prevention (see figure 6).

Figure 6. Symptoms of sugar cane mosaic virus on sugar cane plants [40]

a) Healthy sugarcane plant; b-d) sugarcane with different degrees of infection by sugarcane mosaic virus [40]

Diagnosis and management

Diagnosis

The diagnostic methods traditionally used to identify and control viruses in different crops were based on determining the level of infectivity in different host organisms, called indicator plants. However, this method was expensive to produce. For this reason, most biotechnology laboratories use serological (ELISA) and molecular (molecular hybridisation and PCR) techniques, which require less investment and are highly effective. Serological techniques are based on the use of antibodies that allow the identification of pathogens, while molecular techniques aim to capture the nucleic acids of the virus, either by molecular hybridisation or by PCR, which consists of the exponential amplification of DNA fragments, so that from a few copies of a molecule, multiple copies are obtained, which can be observed by electrophoresis and appropriate staining [44].

In recent years, next-generation sequencing (NGS) technologies have revolutionised plant virus diagnostics. NGS is an efficient and relatively inexpensive method for generating large amounts of genetic data and studying the viral genome. This has led to the development of plant virus diagnostic techniques that do not require prior knowledge of the viral genome. However, despite progress, diagnostic techniques still require further development in the fields of bioinformatics and metagenomics to increase their accuracy. Over time, it is expected that diagnostics will become increasingly effective, widespread and accessible, particularly for developing countries [45].

Management

Given the widespread damage caused by mosaic viruses in vegetable crops and the lack of a cure or treatment, many research projects are looking at ways of controlling and managing these viruses, either through resistant varieties or the use of beneficial organisms. From this perspective, research into plant pathogens is a survival mechanism for agriculture and a way of ensuring food security in many regions of the world. For example, between 2005 and 2006, Sotelo [46] conducted a trial in Chile to determine the effect of MDMV on maize seedlings that had previously been treated with applications of beneficial fungi such as *Trichoderma* spp. and *Bacillus* spp., which act as a barrier to the development of pathogens in seedlings. Approximately ninety days after virus inoculation, various analyses were carried out to determine weight, average plant size and cellular composition to determine the effectiveness of the treatment and reduction in symptoms. At the end of the trial, it was possible to evaluate that the plants treated with *Bacillus* spp. had a positive result in the reduction of the pathogen [46].

The intricate tapestry of mosaic viruses, woven by their diversity and the myriad methods through which they propagate, necessitates a strategic approach rooted in phytosanitary control. To navigate this complex landscape, vigilance through monitoring and early detection becomes the cornerstone upon which effective control stands. Such meticulous oversight ought to extend to regional levels, where the insights garnered serve as vital intelligence for phytosanitary authorities entrusted with safeguarding our crops. It is within this context that the foundation for management strategies takes root, preempting the pathogen's advance. The linchpin of mosaic virus control lies in the initial thwarting of its expansion, achieved through the decisive act of eradicating all afflicted plants. This initial defense, however, only marks the genesis of our comprehensive countermeasure. Variability in mosaic viruses demands tailored tactics, prompting the subsequent execution of measures such as eradicating vectors of the virus, be they aphids, whiteflies, or other carriers. Further augmentation of our defense finds manifestation in the cultivation of plant varieties fortified with resilience against these viral onslaughts.

Yet, when the tools of diagnosis falter in the face of uncertainty, the prudent course remains isolation, and if warranted, the considered obliteration of the potentially infected plant. It is a somber but necessary act, undertaken to preclude the dissemination of a possible viral affliction. In essence, mosaic virus control is a symphony of strategies, orchestrated in harmony with the unique intricacies of each viral manifestation. From vigilant surveillance and astute detection to the resolute culling of infected hosts, and the intricate choreography of obliterating vectors, this multifaceted approach stands as our bulwark against the threat of mosaic viruses.

Conclusion

In a world where agriculture plays a crucial role in food supply and the economy, a thorough understanding of mosaic viruses and their effects is essential. Through this comprehensive analysis, we have unravelled the complexity of these pathogens, their symptomatic similarities and their potential threat to food and ornamental crops in modern agriculture.

From identification to diagnosis and management, we have explored the different stages of dealing with the presence of these viruses in agricultural fields. As we delve deeper into the subject, it becomes clear that the lack of effective treatment is a major challenge that we need to address. Not only do mosaic viruses cause similar symptoms in different crops, they can also cause significant economic losses.

The scale of their impact is not limited to the boundaries of an agricultural parcel; their reach extends to the economic and food stability of entire regions. The imbalance that these viruses can cause is a wake-up call for governments, especially in developing countries, to take decisive action. The implementation of epidemiological surveillance programmes and the training of local farmers are essential steps to prevent infection and mitigate the harmful consequences.

In the specific case of Colombia, the need to provide guidance and support to farmers facing these challenges is evident. The lack of training and resources to deal with mosaic virus situations is a problem that needs to be urgently addressed. The establishment of regional diagnostic strategies and early control measures is essential to prevent the spread and outbreak of epidemics that could devastate crops and the agricultural economy.

The role of the plant trade is also crucial in this journey towards more effective management of mosaic viruses. Awareness of the need to quarantine and destroy infected plant material can make a difference in preventing the spread of these viruses. This will not only ensure plant health, but also consumer confidence in agricultural products. In summary, our comprehensive analysis has led us to understand the urgent need for concerted action. Knowledge of mosaic viruses, their impact and prevention and control measures are essential to ensure food security and economic stability. By working together, the public and private sectors, and empowering farmers with information and training, we can build a more resilient and prosperous agricultural future where the threat of mosaic viruses is met with determination and wisdom.

Consent for publication

The authors read and approved the final manuscript.

Competing interest

The authors declare no conflict of interest. This document only reflects their point of view and not that of the institution to which they belong.

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Artículo de Reflexión

Ciencias Biológicas y Agrícolas

Agroecología, policrisis global y transformación de sistemas alimentarios

Agroecology, global polycrisis and the transformation of food systems

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Resumen

El objetivo de esta reflexión es destacar el papel estratégico de la agroecológica para guiar al mundo hacia una transición de agricultura resiliente, biodiversa y productiva, capaz de producir local y regionalmente suficiente cantidad de alimentos sanos y accesibles para toda la humanidad a pesar de las múltiples crisis que afectan al planeta. Incluso antes del conflicto armado entre Rusia y Ucrania, la economía mundial sufría las repercusiones de varias crisis: climática, COVID-19 y el aumento de los costos de insumos y alimentos, con consecuencias devastadoras para las personas pobres de los países de bajos ingresos. La guerra en Ucrania, un país "granero" para el mundo, está profundizando estos desafíos en una escala sin precedentes. No hay duda de que el sistema alimentario mundial actual necesita una reforma profunda masiva. Está siendo desgarrado por la desigualdad, el hambre, la destrucción ambiental, la crisis climática, los abusos a los derechos humanos y de los trabajadores. La agroecología presenta una alternativa viable, incluyendo una verdadera reforma agraria que asegure que los derechos de uso y manejo de las tierras, los territorios, el agua, las semillas, y la agrobiodiversidad estén en manos de los y las campesinas quienes producen los alimentos y no del sector empresarial. Como alternativa viable al sistema alimentario industrial, la agroecología provee principios y prácticas para apoyar a los pequeños agricultores producir alimentos para sus comunidades y alimentar al mundo de manera sostenible y saludable.

Abstract

The aim of this reflection is to highlight the strategic role of agroecology in guiding the world towards a transition of resilient, biodiverse and productive agriculture, capable of producing locally and regionally sufficient amounts of healthy and accessible food for all humanity despite the multiple crises affecting the planet. Even before the armed conflict between Russia and Ukraine, the world economy was reeling from various crises: climate, COVID-19, and rising food and input costs, with devastating consequences for poor people in low-income countries. The war in Ukraine, a "breadbasket" country for the world, is deepening these challenges on an unprecedented scale. There is no doubt that the current global food system needs a massive deep reform. It is being torn apart by inequality, hunger, environmental destruction, the climate crisis, human and worker rights abuses. Agroecology presents a viable alternative, including a true agrarian reform that ensures that the rights to use and manage the land, territories, water, seeds, and agrobiodiversity are in the hands of the peasants who produce the food and not from the business sector. As a viable alternative to the industrial food system, agroecology provides principles and practices to support small farmers to produce food for their communities and feed the world in a sustainable and healthy way.

Introducción

Las duras realidades del cambio climático son cada vez más visibles y peligrosas en todo el mundo, según la última evaluación del IPCC [1]. Los expertos proyectan que en las próximas décadas, el cambio climático aumentará en todas las regiones y que un calentamiento global de 1.5°C entre los años 2030 y 2052, estará relacionado con un aumento de las olas de calor, las estaciones cálidas más largas y estaciones frías más cortas [2] La concentración actual de gases de efecto invernadero es >500 ppm CO2-e, lo que de acuerdo con el IPCC [1], le otorga a la Tierra, solo un 66% de posibilidades de no superar un calentamiento de 2°C, nivel que superaría los umbrales críticos de tolerancia para la agricultura y los humanos [3].

La mayoría de las evaluaciones cuantitativas de los impactos del cambio climático en los sistemas alimentarios, muestran que el cambio climático, afectará negativamente la seguridad alimentaria (aumentando en 170 millones el número de personas adicionales en riesgo de hambre para 2080) al alterar la producción y la distribución, el acceso y la estabilidad del suministro de alimentos [4]. Los extensos resultados compilados y publicados utilizando cuatro métodos analíticos indican que cada aumento de grado Celsius en la temperatura media mundial reduciría, en promedio, los rendimientos mundiales de trigo en un 6.0%, arroz en un 3.2%, maíz en un 7.4 % y soja en un 3.1%, cuatro cultivos que aportan 2/3 de las calorías globales [5].

No obstante, el cambio climático constituye solo una manifestación de una cascada de catástrofes que amenazan el modelo de agricultura industrial que cubre el 80% de la tierra cultivable a escala global con monocultivos vulnerables genéticamente homogéneos y ecológicamente estrechos [6], los cuales son dependientes de grandes cantidades de insumos agroquímicos, en lo que respecta a más de 5.2 billones de libras de pesticidas y 186.67 millones de toneladas de fertilizantes químicos que se inyectan finalmente a la biosfera en mediciones anuales [7,8].

El objetivo de esta reflexión es destacar el papel estratégico de la agroecología para guiar al mundo en una transición hacia una agricultura resiliente, biodiversa y productiva, capaz de producir local y regionalmente suficiente cantidad de alimentos sanos y accesibles para toda la humanidad a pesar de las múltiples crisis que afectan al planeta.

La transformación de los sistemas alimentarios

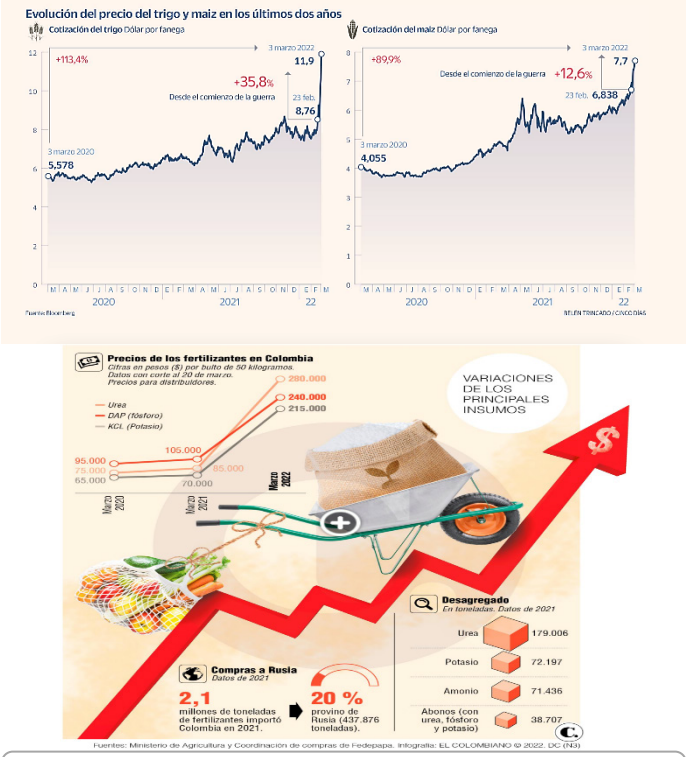
Los sistemas alimentarios son responsables de aproximadamente el 60% de la pérdida de biodiversidad terrestre mundial y de aproximadamente el 31% de las emisiones globales de gases efecto invernadero (GEI) [9], lo que torna al sistema alimentario mundial en uno de los principales impulsores del cambio climático. Además, aunque los sistemas de producción industrial cubren más del 70% de la tierra cultivable y utilizan cantidades masivas de agua y combustibles fósiles, produciendo solamente alrededor del 30% de los alimentos que se consumen en todo el mundo [10].

La dependencia agroquímica de los sistemas alimentarios, recientemente ha sido expuesta por el conflicto armado entre Rusia y Ucrania [11, 12], escenario que disparó los precios de los fertilizantes junto con el aumento de los precios de los alimentos, ligado a las exportaciones de trigo restringidas por la guerra, lo que aumenta la perspectiva de escasez mundial de alimentos e inestabilidad política, particularmente en los países que importan granos (ver figura 1). Todo esto se suma a los esfuerzos de los países para recuperarse de la pandemia de COVID-19 que alteró los sistemas alimentarios en todo el mundo, afectando la seguridad alimentaria y la nutrición de las poblaciones rurales y urbanas al afectar la mano de obra estacional, limitando el acceso al suministro de insumos y forzando el cierre de mercados, interrumpiendo las redes de transporte y aumentando el riesgo de escasez de oferta [6].

Estos escenarios plantean una pregunta clave de supervivencia para la humanidad: *"¿qué tan preparado está nuestro sistema alimentario industrial para enfrentar la policrisis en términos de escasez de energía, escasez de agua, degradación ambiental, pérdida de biodiversidad, cambio climático, desigualdad económica, inseguridad alimentaria, conflictos militares y otros que afectan al planeta?"* Una cosa es cierta, estos problemas no se pueden abordar de forma aislada, debido a que están interconectados y son interdependientes. Cuando alguno de los problemas se agudiza, los efectos se extienden por todo el sistema, potencializando los otros problemas. Las causas subyacentes de las pandemias son las mismas fuerzas económicas globales y los cambios ambientales que impulsan la pérdida de biodiversidad y el cambio

climático [13]. Como se ha presenciado, la crisis de salud inducida por la pandemia, ha desencadenado rápidamente una crisis económica, la cual se desarrolla en el contexto de una crisis climática, lo que a su vez, exacerba la pandemia y la crisis económica [14,15].

Figura 1. El Impacto de la Guerra en Rusia-Ucrania: Precios de Fertilizantes en Aumento a Nivel Mundial y su Impacto en Colombia



Fuente: Ministerio de Agricultura y Coordinación de Compras de Fedepapa [16].

La naturaleza sistémica de la policrisis reveló la tragedia oculta de la producción animal a escala industrial y de monocultivos interminables que afectan en forma dramática los siguientes elementos fundamentales: *i*)biodiversidad; *ii*) contaminación del suelo y agua; *iii*) la desnutrición; *iv*) obesidad; *v*) enfermedades zoonóticas y *vi*) condiciones de trabajo miserables para los trabajadores migrantes que socava en los medios de vida de los pequeños agricultores [17,18]. Del mismo modo, reveló cuán estrechamente están vinculadas la salud humana, la sanidad vegetal, del suelo, la salud animal y la ecológica; además está conduciendo a la comprensión de que la forma en que se practica la agricultura industrial, plantea riesgos importantes para el bienestar humano y la integridad del ecosistema. La agricultura moderna está reprobando el test de resiliencia y resulta inadecuada para alimentar al mundo frente a los impactos climáticos. La continuación del paradigma agrícola actual no es una opción y el cambio transformador es fundamental para igualar (y con suerte revertir) la progresión implacable de las amenazas ambientales vinculadas a la expansión continua de la agricultura industrial.

La agenda internacional y la población humana

La narrativa convencional aún influencia la agenda internacional argumentando que para el año 2050, la población humana alcanzará los 9800 millones, lo que supuestamente requerirá un aumento del 100 al 110% en la producción agrícola mundial [19]. Para lograr esto, los intereses alineados con el agronegocio, argumentan que se necesita una intensificación sostenible para evitar en la medida de lo posible, la expansión de las tierras agrícolas y la presión sobre los ecosistemas naturales. Esta perspectiva maltusiana, es precisamente la que ha dominado el desarrollo agrícola desde la revolución verde y, a pesar de todos los esfuerzos de la agroindustria por aumentar la producción para acabar con el hambre, la desnutrición en todas sus formas y el acceso insuficiente de alimentos nutritivos, sigue siendo la realidad de casi mil millones de personas [20].

El hambre actual no es una consecuencia de detrimentos sustanciales en los rendimientos o suministros mundiales que no pueden satisfacer la demanda; más bien, se debe a la pobreza, a la distribución deficiente de alimentos, al desperdicio de alimentos, la falta de acceso a la tierra y otros aspectos del sistema alimentario. Una visión productivista del hambre no logra alterar la distribución estrechamente concentrada del poder económico que determina por qué masas de personas pobres y vulnerables carecen de acceso a los alimentos, o por qué los pequeños agricultores que producen entre el 50 y el 70% de los alimentos mundiales en solo el 30% de las tierras cultivables, aún carecen de acceso a semillas, agua y tierra para producir aún más [21].

A pesar de este reconocimiento, la mayoría de las recomendaciones se limitan al ajuste o reforma del sistema alimentario y agrícola actual con un arsenal de nuevas tecnologías que incluyen entre otras: *i*) edición de genes; *ii*) aplicación de nuevas biotecnologías; *iii*) agricultura digital; *iv*) agricultura de precisión; *v*) nuevos enfoques disfrazados ecológicamente como la agricultura climáticamente inteligente; *vi*) agricultura regenerativa; *vii*) agricultura para captar carbono, todas las cuales

representan "soluciones basadas en el mercado y propuestas tecnológicas arriesgadas de "cero neto" impulsadas por gobiernos controlados por corporaciones transnacionales, filántropos, los principales medios de comunicación y un numero de ONGs internacionales" [22].

Estos enfoques son parte de un proceso de cooptación, colonización e institucionalización de la agroecología, intentando despojarla de su dimensión socio- política. Ninguno de estos enfoques aborda los principales impulsores políticos y económicos de la actual crisis del sistema alimentario, a saber: la estructura de los monocultivos y el poder corporativo que la nutre; el alentar e incidir sobre los agricultores y propietarios de tierras forestales para que adopten prácticas enfocadas en el secuestro del dióxido de carbono en el suelo y en la biomasa para mitigar el cambio climático; escenario que plantea diversas preocupaciones desde el desplazamiento de pequeños agricultores hasta el socavamiento de la soberanía alimentaria. La Vía Campesina, llama a salir urgentemente de la lógica de la compensación para reducir las emisiones de GEI, y en su lugar, plantea promover sistemas agrarios basados en sistemas agrícolas diversificados de pequeña escala que enfríen el planeta [23].

Otras propuestas, como la reducción del desperdicio de alimentos y la adopción de una dieta sostenible para reducir el costo ecológico del sistema alimentario actual, son políticamente ingenuas, debido a que impiden el reconocimiento de la magnitud del desafío, ignorando las inequidades de que son víctimas las personas pobres y vulnerables, quienes no pueden permitirse esos lujos dietéticos y terminan pagando los costos de la pérdida de biodiversidad y el colapso climático al que no contribuyeron.

La agroecología y su potencial transformador

El cambio del sistema alimentario industrial solo puede lograrse mediante la promoción de políticas que aseguren que los pequeños agricultores, tengan acceso real y seguro a la tierra, al agua, semillas y razas de animales para producir alimentos basados en prácticas agroecológicas, distribuyendo diversos alimentos localmente a través de mercados solidarios y haciéndolos accesibles a todos los segmentos de las sociedades urbanas y rurales, en particular, para los que sufren hambre y los que padecen inseguridad alimentaria.

La agroecología tiene un potencial transformador para hacer frente a los desafíos futuros que plantean las rupturas ecológicas como el cambio climático y el COVID-19 [6,24], al exhibir altos niveles de diversidad y resiliencia; ambas propiedades emergentes conocidas por reducir el riesgo del cambio climático u otras amenazas, al tiempo que brindan rendimientos razonables; además de proporcionar servicios ecosistémicos que resultan clave para la sociedad.

La agroecología muestra un camino diferente al proporcionar los principios sobre cómo diseñar y gestionar sistemas agrícolas más capaces de resistir futuras crisis, ya sean brotes de plagas, pandemias, alteraciones climáticas o colapsos financieros, territorializando la producción y el consumo de alimentos. Miles de iniciativas agroecológicas en todo el mundo que revitalizan los sistemas agrícolas tradicionales y campesinos que han resistido la prueba del tiempo mejoran la soberanía alimentaria al tiempo que contribuyen a la conservación de la biodiversidad a nivel de finca y paisaje. El incremento de la diversidad de especies de plantas y la diversidad genética aumenta la resiliencia general de los sistemas alimentarios frente a los nuevos cambios ambientales y fluctuaciones climáticas [25] (ver figura 2).

Figura 2. Resistencia al impacto del Huracán Mitch: Comparación entre fincas agroecológicas diversificadas y fincas en monocultivo

Las observaciones del desempeño agrícola después de eventos climáticos extremos (huracanes y sequías) en las últimas dos décadas han revelado que la resiliencia a los desastres climáticos está estrechamente relacionada con fincas que exhiben mayores niveles de biodiversidad. Los diseños agroecológicos promueven fincas insertas en una matriz paisajística compleja, con semillas locales adaptadas desplegadas en sistemas de cultivo diversificados manejados con suelos ricos en materia orgánica y técnicas de conservación y cosecha de agua [10].

La identificación de sistemas que han resistido eventos climáticos recientes o en el pasado y la comprensión de las características agroecológicas de dichos sistemas que les permitieron resistir y/o recuperarse de eventos extremos es cada vez más urgente. Esto se debe a que los principios y prácticas de resiliencia derivados que subyacen en las fincas exitosas pueden difundirse a miles de agricultores a través de métodos Campesino a Campesino y redes de faros agroecológicos, de manera de masificar las prácticas agroecológicas que mejoran la resiliencia de los agroecosistemas [10]. Tales iniciativas han tenido éxito en la reconstrucción de sistemas agrícolas en áreas afectadas por huracanes en países como Cuba y Puerto Rico.

No obstante, "ecologizar" la revolución agrícola requerida, no será suficiente para reducir el hambre y la pobreza, conservar la biodiversidad y mejorar la resiliencia climática. El cambio transformador en la agricultura implica el desmantelamiento del complejo industrial agroalimentario y el control corporativo sobre la producción y el consumo. Requiere restaurar los sistemas alimentarios locales compuestos por redes alimentarias alternativas y alianzas solidarias entre productores y consumidores. Los mercados provistos por fincas biodiversas, orientadas a mercados locales y regionales, son más flexibles para responder a cambios y perturbaciones. Los mercados territoriales tienden a ser menos vulnerables a los cambios de precios y al colapso de las cadenas de suministro centralizadas al reducir la dependencia de los productores y consumidores de las grandes corporaciones que controlan las cadenas de suministro globales propensas a las perturbaciones políticas, económicas y climáticas [26].

La policrisis nos recuerda la urgente necesidad de que la producción de alimentos, debiera estar en manos de pequeños productores, campesinos y agricultores urbanos, que produzcan bajo los principios agroecológicos de diversidad, eficiencia y sinergia. Esta es la única forma de garantizar el suministro de alimentos frescos, a precios asequibles en los mercados locales, incluso en medio de perturbaciones climáticas, pandémicas u otras.

Sin embargo, el peso de cambiar el sistema alimentario no puede descansar solo sobre los hombros de los agricultores. Para ello, resulta crucial sensibilizar a los habitantes urbanos sobre la importancia y el mantenimiento de los sistemas agrícolas biodiversos y adaptables asociados con la agricultura familiar, y la comprensión de qué comer es un acto tanto ecológico como político; cuando los consumidores apoyan a los agricultores locales, en vez de la cadena alimentaria corporativa, la cual es más vulnerable que las redes alimentarias de los pequeños agricultores a las interrupciones naturales, causadas por los humanos, crean sostenibilidad y resiliencia socioecológica.

Consideraciones finales

El reciente informe de la IPCC[1] arroja una luz destacada sobre el creciente reconocimiento de la agroecología como una vía agrícola de importancia crítica. Este enfoque, en constante ascenso, no solo promete una serie de ventajas socioeconómicas y ambientales significativas para las familias rurales, sino que también desempeña un papel fundamental en la alimentación equitativa y sostenible de las poblaciones urbanas.

Es importante subrayar que el cambio transformador que se busca en la agricultura no existe en un vacío aislado. Debe ir de la mano de una transformación más amplia que abarque la transición desde una economía predominantemente orientada al mercado hacia una economía solidaria. También implica el alejamiento de la dependencia de los combustibles fósiles hacia una adopción decidida de fuentes de energía renovable. Además, se requiere una reconfiguración del sistema alimentario, alejándonos del control ejercido por las grandes corporaciones y moviéndonos hacia modelos cooperativos que fomenten la participación y la equidad en la producción y distribución de alimentos.

A pesar de las complejidades y desafíos que acompañan este proceso de cambio, es esencial comprender que la agroecología no es simplemente una técnica agrícola, sino una filosofía y un movimiento que encarna la esperanza de un futuro más sostenible. Este movimiento es

impulsado por miles de agricultores de todo el mundo, en su mayoría campesinos e indígenas, que perseveran con tenacidad en la transformación de sus prácticas agrícolas. Utilizan sistemas diversificados, promoviendo la biodiversidad, la salud del suelo y la resiliencia frente a eventos climáticos extremos.

Estos esfuerzos, realizados en condiciones a menudo adversas y sin el apoyo adecuado, representan auténticos oasis de esperanza en un contexto de policrisis y desigualdades sociales profundas. Estos agricultores y sus prácticas ejemplares no solo apuntalan el camino hacia un futuro más sostenible, sino que también nos recuerdan la importancia de unirnos como sociedad para abrazar un enfoque que promueva la justicia social y la salud del planeta que todos compartimos.

Lamentablemente, el avance hacia la implementación de estas soluciones se encuentra obstaculizado por la falta de voluntad política en numerosos gobiernos, lo que retrasa la adopción de medidas efectivas y urgentes destinadas a reorganizar integralmente nuestro sistema. En este escenario de inercia y resistencia al cambio, destaca el admirable esfuerzo de miles de agricultores en todo el mundo. A pesar de la falta de respaldo y de un ambiente desafiante, perseveran tenazmente en la transformación y manejo de sus paisajes agrícolas.

Estos agricultores optan por sistemas de cultivos intercalados, prácticas agroforestales y sistemas silvopastoriles que incorporan una diversidad genética en sus cultivos, así como otros enfoques agrícolas diversificados. Esta elección no solo mejora la biodiversidad de sus terrenos, sino que también revitaliza la salud de los suelos y fortalece la resiliencia de sus sistemas agrícolas ante los rigores de eventos climáticos extremos.

Es fundamental destacar que la gran mayoría de estos esfuerzos lo lideran campesinos e indígenas, cuyas prácticas ejemplares encarnan auténticos oasis de esperanza. En un mundo marcado por la presión abrumadora del deterioro ecológico y la desigualdad social, estos agricultores representan puntos de partida para una nueva visión. Sus acciones no solo indican un camino hacia un futuro más sostenible, sino que también enfatizan la necesidad apremiante de unirnos como sociedad para abrazar un enfoque que promueva la justicia social y la restauración de la salud de nuestro planeta en policrisis.

Consentimiento de publicación

Los autores leyeron y aprobaron el manuscrito final.

Conflicto de interés

Los autores declaran no tener conflicto de interés. Este documento solo refleja sus puntos de vista y no el de la institución a la que pertenecen.

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