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Digital Tools in Dermatology: Acceptance and unmet needs in the digital transformation of healthcare

Dissertation
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Michael Tobias Hindelang

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"We are drowning in information, while starving for wisdom."

— Edward O. Wilson

To my late father, who taught me to love learning and to never stop asking questions.

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List of abbreviations

AD	Atopic Dermatitis
AI	Artificial Intelligence
CU	Chronic Urticaria
CSU	Chronic Spontaneous Urticaria
DHS	Digital Health Services
DLQI	Dermatology Life Quality Index
DMP	Disease Management Program
eHEALS	eHealth Literacy Scale
ePRO	electronic Patient-Reported Outcome
GDPR	General Data Protection Regulation
HES	Hypereosinophilic Syndrome
HTA	Health Technology Assessment
ICT	Information and Communication Technology
LMU	Ludwig-Maximilians-University of Munich
mHealth	Mobile Health
RCT	Randomized Controlled Trial
SPSS	Statistical Package for the Social Sciences
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TAM	Technology Acceptance Model
TUM	Technical University of Munich
UCT	Urticaria Control Test
UTAUT	Unified Theory of Acceptance and Use of Technology

List of peer-reviewed publications

Included in the cumulative dissertation

1. **Hindelang M**, Zink A, Knitza J, Darkow R, Welcker M, Biedermann T, May S, Muehlensiepen F. Acceptance and perceived usefulness of digital health services in the management of chronic urticaria: a survey of patients and physicians. BMC Health Serv Res. 2025 Jul 2;25(1):894. doi: 10.1186/s12913-025-13043-7. PMID: 40604824; PMCID: PMC12224775.
2. **Hindelang M**, Sitaru S, Fischer C, Biedermann T, Zink A. Bridging the Gap through Telemedicine: A Pilot Study on the Acceptance and Use of Teledermatology in Chronic Spontaneous Urticaria. JDDG – Journal of the German Society of Dermatology. 2024;23(1):40–53. doi: 10.1111/ddg.15557. PMID: 39428756; PMCID: PMC11711928.
3. **Hindelang M**, Wecker H, Biedermann T, Zink A. Continuously monitoring the human machine? – A cross-sectional study to assess the acceptance of wearables in Germany. Health Informatics J. 2024 Apr–Jun;30(2):14604582241260607. doi: 10.1177/14604582241260607. PMID: 38900846.
4. **Hindelang M**, Sitaru S, Zink A. Tracking Public Interest in Rare Diseases: A Web Search Analysis of Eosinophilic Disorders in Germany. JMIR Infodemiology. 2025 May 26;5:e69040. doi: 10.2196/69040. PMID: 40418815.

Included as appendix of the dissertation

5. **Hindelang M**, Sitaru S, Zink A.
   Transforming Health Care Through Chatbots for Medical History-Taking and Future Directions: Comprehensive Systematic Review.
   JMIR Med Inform. 2024 Aug 29;12:e56628. doi: 10.2196/56628. PMID: 39207827; PMCID: PMC11393511.
6. **Hindelang M**, Tizek L, Harders C, Sommer-Eska L.
   Hybrid care potential of teledermatology: The importance of linking digital and physical practice and acceptance of online services.
   Health Sci Rep. 2024 Jul 9;7(7):e2241. doi: 10.1002/hsr2.2241. PMID: 38983681; PMCID: PMC11231929.

Additional publications (not included in the dissertation)

7. Wecker H, Ziehfreund S, **Hindelang M**, Zink A.
   Change of Perspective: Impact of COVID-19 Pandemic on Axial Spondyloarthritis-Related Web Searches in Germany.
   Scientific Reports. 2024.
8. **Hindelang M**, Sitaru S, Fischer C, Biedermann T, Zink A.
   Überbrückung der Versorgungslücke durch Telemedizin: Pilotstudie zur Akzeptanz und Nutzung der Teledermatologie bei Urtikaria.
   J Dtsch Dermatol Ges. 2025 Jan;23(1):40–53. German. doi: 10.1111/ddg.15557_g.
   Epub 2025 Jan 8. PMCID: PMC11711920.

Additional publications

7. **Hindelang M**, Klimova D, Domenech A, Kasujee I, Biedermann T, Zink A. Understanding Clinical Inertia in Atopic Dermatitis: A Mixed-Methods Study of Barriers to Treatment Escalation. (Submitted)

List of conference contributions and presentations

1. **Hindelang M.** Digitale Versorgung bei Urtikaria. New Ideas for Medicine, 2022, München.
2. **Hindelang M**, Wecker H, Biedermann T, Zink A. Exploring Wearable Technology Acceptance for Health Monitoring: Insights from User Behaviour and Non-User Perspectives. Poster, 22nd German Conference on Health Services Research, 2023. DOI: 10.3205/23dkvf106.
3. **Hindelang M**, Wecker H, Biedermann T, Zink A. Wearable Technology Acceptance for Monitoring. Oral presentation, German Conference on Health Services Research, 2023.
4. **Hindelang M.** Evaluierung einer digitalen Lösung zur Optimierung der Versorgung von PatientInnen mit chronischer Urtikaria. New Ideas for Medicine, November 2023, München.
5. **Hindelang M.** Moderation, New Ideas for Medicine, 23 November 2024, München.
6. **Hindelang M**, Sitaru S, Fischer C, Zink A. What is the Acceptance of Digital Care for Patients with Chronic Urticaria? Poster P029, DERMATOLOGIE kompakt & praxisnah, 2024. DOI: 10.1111/ddg.15369_g
7. **Hindelang M**, Ziehfreund S, Gasteiger C, Zink A. Unmet Needs and Spatiotemporal Variation in Vitiligo: A Retrospective Longitudinal Web Search Analysis. Poster, ISPOR Europe 2024 – Poster Session 3, Value in Health. 2024;27(12):S253. DOI: 10.1016/j.jval.2024.09.1535
8. **Hindelang M.** Moderation, New Ideas for Medicine, 24 May 2025, München.
9. **Hindelang M**, Sitaru S, Zink A. Chatbots im Gesundheitswesen: Rolle, Effektivität und zukünftiges Potenzial bei der Anamneseerhebung – eine systematische Literaturübersicht. Poster P107, DDG Kongress 2025. J Dtsch Dermatol Ges. First published: 29 April 2025. DOI: 10.1111/ddg.15783_g
10. **Hindelang M**, Biedermann T, Zink A, Knitza J, Darkow R, Welcker M, May S, Mühlensiepen F. Akzeptanz und Nützlichkeit digitaler Gesundheitstechnologien bei der Behandlung von chronischer Urtikaria: Eine Umfrage unter Patient:innen und Ärzt:innen. Poster P023, DDG Kongress 2025. J Dtsch Dermatol Ges. First published: 29 April 2025. DOI: 10.1111/ddg.15783_g
11. **Hindelang M**, Zink A. Power Happy Pso – Finalist project presented at the PsOlve Innovation Platform Global Pitch Day. Oral presentation, 20 June 2025, Rome, Italy.
12. **Hindelang M.** Teledermatology for Inflammatory Skin Diseases: The 'Love It' Case. Plenary Session 3, SPIN Congress 2025, 27 June 2025, Paris, France.

1. Contribution to the publications

All scientific work presented in this dissertation was carried out under the supervision of my thesis advisory committee (TAC) and especially under my supervisor, Prof. Dr. Dr. Alexander Zink, MPH, MBA, at the Technical University of Munich. He supported me in all my research work, including the initial research questions, the selection of suitable study designs, and the publication process, including the selection of target journals. Prof. Dr. Rolf Holle and Prof. Dr. Michael Ingrisch, who served as members of my TAC, have made valuable contributions to the development of the conceptual focus and scientific quality based on feedback provided during TAC meetings.

1.1 Contribution to paper I

I adapted the study protocol and ethics application to our study center using the study concept designed by the main study center. I created the patient information materials for our study center and coordinated the approval process with the ethics committee. I oversaw the entire data collection process at our study site: identifying participants, recruiting them, and organizing the study workflow. After data cleaning, I performed all statistical analyses, interpreted the results, and wrote the entire manuscript draft. I was the first author and incorporated feedback from the co-authors into the manuscript. I revised all manuscript versions in the peer review process and was the correspondence author for the five reviewers' feedback.

1.2 Contribution to paper II

I developed the methodological approach based on a concept by Maximilian Schielein (a former colleague from the working group) and my supervisor, Prof. Alexander Zink. I wrote the entire study protocol for the ethics committee and submitted the application for approval by the Ethics Committee of the Technical University of Munich. In consultation with the institution's data protection officer, I compiled the documentation on data protection, observing all ethical and procedural rules. I selected the instruments ultimately used in the study and integrated validated instruments (e.g., urticaria control test, dermatological quality of life index, satisfaction and usability questionnaires), drafted patient information and consent forms, operationalized the digital care concept, trained the participating physicians, and coordinated the video consultations. I recruited patients, coordinated >100 (5 Visits x 23 patients over 1 year) online visits for the study, collected and processed data, and performed the analysis. As the corresponding author, I led the entire peer review process, including the resubmission of the manuscript and responses to the reviews. I discussed the results with my co-authors and incorporated the peer review comments in the final manuscript.

1.3 Contribution to paper III

I was responsible for developing the study design, including formulating research objectives, creating the questionnaire, and drafting the study protocol. I submitted the ethics application to the Ethics Committee of the Technical University of Munich. I coordinated the complete data protection documentation and consultation process with the institutional Data Protection Officer. I planned and organized participant recruitment strategies across multiple channels, including online platforms, outpatient clinics, and public events such as national health fairs. I supervised and conducted the data collection, ensured data integrity, and prepared the data for analysis. I performed the complete statistical analysis, derived the key findings, and contextualized the results within the broader literature. I wrote the full manuscript, served as the corresponding author, and led the entire peer-review process, including revisions and responses to reviewers.

1.4 Contribution to paper IV

I was responsible for developing the entire keyword selection strategy, formulating the categorization system, and developing a framework for spatiotemporal analysis across 16 German federal states and the cities of interest across Germany. I conducted all data preprocessing steps for cleaning, normalization, and stratification by all subcategories. I performed the complete statistical analysis, including seasonality modeling and cross-regional comparison. I visualized the results and interpreted the findings in close collaboration with the co-authors. I wrote the entire manuscript and served as the corresponding author, coordinating the whole peer-review process, including preparing revision documents and point-by-point responses. Additionally, I ensured methodological rigor and coherence throughout the project and took responsibility for all communication with the journal.

1.5 Contribution to paper V (Appendix)

I conceived the study concept jointly with Prof. Alexander Zink and was responsible for designing and conducting the systematic review. I registered the review protocol in the PROSPERO international prospective register of systematic reviews (CRD42023410312). I developed the entire PICOS-based search strategy from scratch, which included defining all search terms, Boolean logic, and inclusion/exclusion criteria. This strategy was iteratively refined and finalized in consultation with my supervisor, Prof. Alexander Zink. I conducted comprehensive literature searches across six major databases—PubMed, Embase, MEDLINE (via Ovid), Scopus, Open Science Framework, and relevant reference lists—tailoring each search strategy to the respective indexing system. I managed the deduplication and led the two-stage screening process: title/abstract screening and full-text screening. I performed the primary screening, while Sebastian Sitaru acted as the second reviewer in duplicate screening, with discrepancies resolved through discussion. I designed and piloted a structured data extraction form in Microsoft Excel. I systematically collected the data on study design, setting, population, intervention characteristics, comparator, outcomes (feasibility, acceptability, effectiveness), and study quality. I performed all data extraction and analysis, including risk of bias assessment using the STROBE checklist for observational studies and RoB 2 where applicable. I carried out a narrative synthesis following PRISMA guidelines, created all summary tables and visualizations using R, and ensured the completeness of the PRISMA flowchart. Furthermore, I wrote the full manuscript, managed all co-author feedback, and led the peer-review process as corresponding author. I coordinated all project timelines, methodological discussions, and reporting standards to ensure the quality and integrity of this comprehensive systematic review.

1.6 Contribution to paper VI (Appendix)

I co-developed the survey instrument, ensuring the items aligned with our research objectives. I contributed to refining the item wording and structuring the questionnaire to maximize clarity and data utility. I was responsible for the complete data preparation, including data cleaning, quality control, and coding for statistical analysis. I conducted all descriptive and inferential statistical analyses, including subgroup and regression modeling. I also took the lead in interpreting the results in collaboration with Christiane Harders and Leonie Sommer-Eska, incorporating their feedback regarding practical implications in teledermatology. I drafted the full manuscript, including all visualizations and tables, and managed the peer-review process as the corresponding author. I was responsible for integrating revisions, coordinating responses to reviewers, and ensuring timely resubmissions. In addition, I oversaw the entire operational coordination of the project, from aligning timelines across stakeholders to managing data from the OnlineDoctor platform, supporting publication planning, and ensuring all components were completed in line with STROBE and Open Access standards.

2. Introductory summary

2.1 Background and relevance

Common chronic inflammatory dermatoses such as chronic spontaneous urticaria (CSU), atopic dermatitis, and psoriasis place a significant burden on patients and healthcare systems worldwide (1–6). These diseases have not only visible but also invisible consequences, which often include itching, psychological distress, stigmatization, and a reduced quality of life (7–10). Despite advances in treatment methods, these diseases are often diagnosed too late, inadequately treated, and with limited access to specialized care (6,11–13). This is particularly true in rural areas where patients present with rare or complex clinical phenomena (13–15).

The digitalization of healthcare has proven to be an effective response to this problem (16,17). This can have a particularly transformative impact in dermatology and chronic conditions that require frequent follow-up examinations and visual diagnosis (Figure 1). Teledermatology, wearables, mobile health applications, and AI-powered triage systems are just a few examples that offer the opportunity to improve accessibility, facilitate remote disease monitoring, and create better continuity of care (18–20). However, their actual uptake in daily practice is still limited because of barriers, including digital readiness, data security, and system integration (21–23).

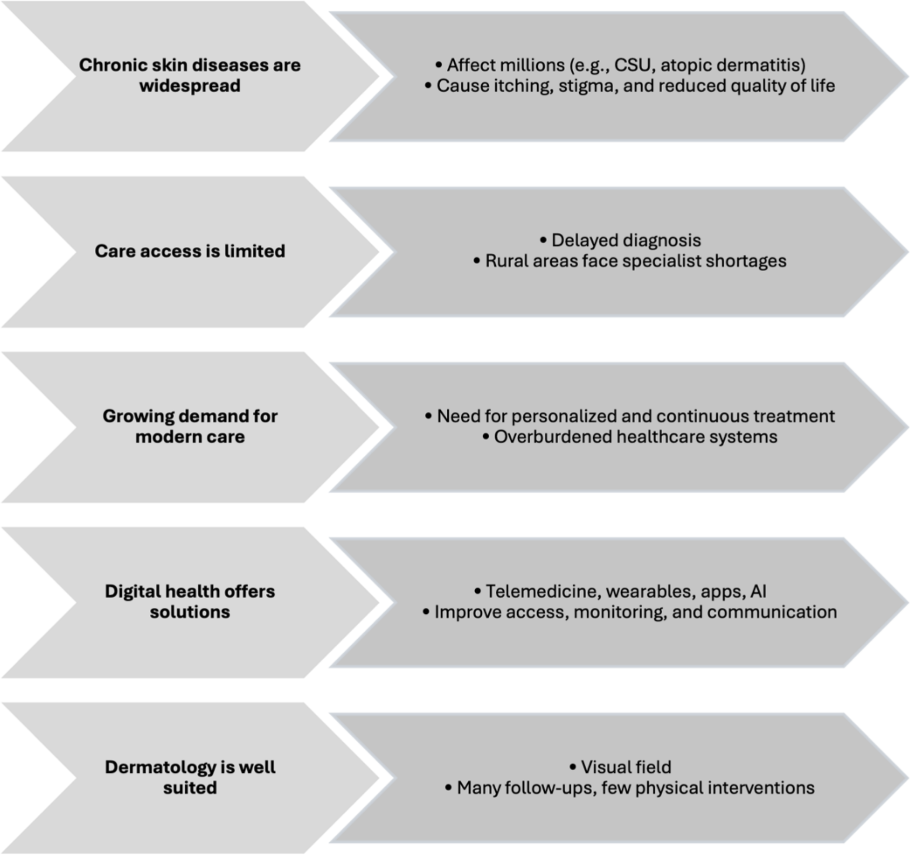

Figure 1: Key drivers for implementing digital health in dermatology

In this context, it is important to assess the technical feasibility and the level of acceptance, perceived benefits, and public engagement of these tools. Patients and physicians are not just passive recipients of innovations. Implementation success depends on their attitude, experience, and trust in digital devices. At the same time, digital behavior, such as using health-related queries on internet search engines, can provide useful indications of (lack of) awareness, unmet need, and disease burden at the population level (23,24). This thesis aims to contribute to these complex questions by examining digital approaches in dermatology in six studies, including telemedicine, acceptance studies, chatbot analyses, and infodemiological research. Taken together, they provide a comprehensive overview of digital tools' role in delivering inclusive, responsive, and patient-centered dermatology care.

2.2 Scientific and societal context

2.2.1 Burden of chronic inflammatory skin diseases

Chronic inflammatory skin diseases such as CSU represent a high individual and collective burden. Approximately 0.5–1% of the world's population is affected by chronic urticaria, with prevalence in the US and Japan ranging from 0.23 to 1.1% (25–27). Women and people aged between 30 and 50 are disproportionately affected (3). Symptoms such as chronic itching, swelling, and hives significantly impair quality of life. Approximately 30–40% of patients achieve a DLQI score >10, which corresponds to very severe or extremely severe impairment (28). Psychiatric comorbidities such as anxiety and depression affect up to 40% of patients (29), and severe itching is a major cause of sleep disturbances and emotional distress. CSU is associated with a higher burden on healthcare resources (28,30). Inadequate disease control leads to high direct and indirect treatment costs (5). In Germany, approximately 0.5% of the population suffers from CU, with 60–70% of cases being CSU (31). The proportion is higher in women (0.62%) than in men (0.37%) (31). The German data are consistent with international data and show a significant deterioration in quality of life, with the greatest losses occurring in patients with chronic itching and psychiatric comorbidities. In Europe, studies have shown that 50% of patients experience moderate to extremely severe impairments in daily life and work productivity, as well as high levels of stigmatization and psychological distress (31). Compared to other European countries, the healthcare utilization and costs in Germany are high (32). While >50% of patients do not receive a written prescription, patients with severe disease are often treated by general practitioners, dermatologists, or emergency services (31). Patients must usually endure long waiting times before diagnosis and the start of effective treatment (median 3.8 years), which can be reduced to up to 2.5 years through targeted interventions (33).

2.2.2 Care gaps and systemic challenges

Providing care for patients with chronic skin conditions from a holistic perspective is sometimes impossible in our current healthcare systems (34). Patients often describe fragmented care, a lack of specialists, and long waiting times (35). General practitioners may not be trained in dermatology, and referral pathways are not always clearly defined or appropriate (36). In addition, traditional care models are based on frequent face-to-face meetings, which can lead to logistical challenges and disrupt continuity of care, a significant burden for many chronic conditions that require ongoing care (36). Furthermore, time constraints, communication barriers, and administrative burdens limit physicians' ability to fully engage in patient care. In CSU, for example, many patients are inadequately treated, even though guidelines for this condition and therapeutic options are available (37,38). The reasons for this are complex and range from clinical inertia and inadequate follow-up to insufficient consideration of patient-reported outcomes in treatment decisions. At the systemic level, the introduction of innovative care systems has had to contend with reimbursement rules, digital infrastructure, and data protection requirements. New approaches that can address the factors of access, coordination of care, and “sustained” data-driven patient involvement are needed.

2.2.3 Potential of digital health in dermatology

Digital health technologies offer new ways to meet these needs. Teledermatology enables remote consultation, triage, and follow-up, facilitating access and reducing time to diagnosis. Mobile apps can be used for self-monitoring, symptom recording, and patient education, and wearable devices can enable ongoing quantification of movements and physiological variables (e.g., scratching, skin temperature, or sleep quality) (39,40). The use of AI-based systems, such as image recognition, conversational agents, or more patient support, is increasing in clinical decision support and patient interaction. At the same time, digital epidemiology tools, including internet search engine data, can guide public health responses, uncover growing needs, and complement traditional surveillance methods (41,42). The field of dermatology appears particularly promising for a digital revolution, as it relies heavily on visual diagnoses, involves a relatively small number of physical interventions, and is characterized by many chronic diseases (43). Such technologies may offer a way to replicate and amplify the benefits of these care models while reducing demands on patients and physicians and improving screening, adherence, and outcomes (44). However, their practical implementation will require patient and provider acceptance, sufficient digital literacy, regulatory frameworks, and careful integration into clinical routines.

2.2.4 From innovation to implementation

Although technology is improving, the adoption of digital health solutions in dermatology is uneven. While adoption accelerated during the COVID-19 pandemic, including telemedicine, many of these innovations are still in the pilot phase and are isolated seedlings rather than systematically rolled-out solutions (45). Challenges include technological complexity, lack of training, fragmented infrastructure, and skepticism about clinical effectiveness and data privacy. In addition, many digital tools have limited real-world experience or have been developed without sufficient end-user involvement (46,47). Without collaborative development and validation, tools may not meet the actual needs of patients and providers, resulting in low adoption and sustainability. This dissertation provides empirical evidence of the acceptance, readiness, and perceived usefulness of digital tools in dermatology and may help to narrow the gap between development and implementation. Investigating a broad perspective ranging from telemedicine to wearables to infodemiology, this dissertation demonstrates that data-driven health can be used for routine care and can help address systemic barriers and individual expectations.

2.3 Thematic framework and research questions

2.3.1 Central research themes

This cumulative thesis is based on six articles with different content on digital health in dermatology (Figure 2). Although each study is a distinct entity with specific aims, approaches, and publication context, they are conceptually linked by the overarching areas of digital technologies that form the focus of this thesis. A more detailed summary of the articles can be found under “2.5. Summary of included publications”.

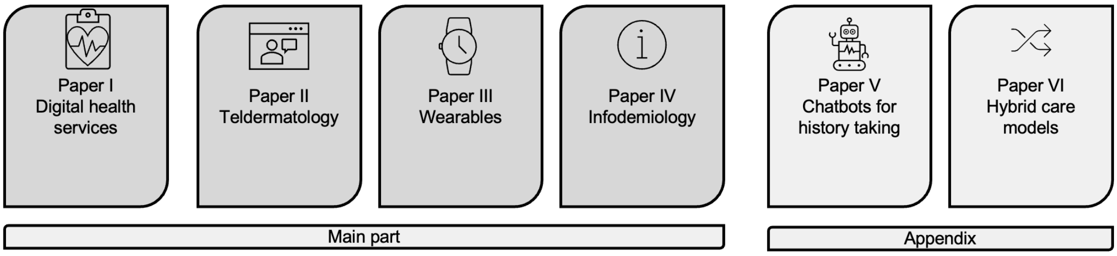

Figure 2: Overview of the thematic structure of articles

Digital health and patient experience

A survey on the perceived usefulness and use of digital tools (e.g., apps, portals) to support the management of chronic urticaria: a quasi-experimental study among patients and physicians. The study shows differences in attitudes, expectations, and digital health literacy (48).

This article can be accessed here: www.doi.org/10.1186/s12913-025-13043-7

Teledermatology

One paper addresses the role of a 12-month teledermatology approach in CSU, analyzing patient and clinician acceptance and feasibility (49). This pilot study was the basis for a nationwide multicenter study (> 20 centers) currently being conducted.

This article can be accessed here: www.doi.org/10.1111/ddg.15557

Wearables and skin monitoring

A third study discusses wearables to monitor dermatological symptoms that can be continuously digitally monitored, such as scratching behavior and skin conditions in German adults (50).

This article can be accessed here: www.doi.org/10.1177/14604582241260607

Infodemiology and search behavior
Another study uses infodemiological approaches to monitor public search behavior related to eosinophilic disease in Germany (51). Infodemiology seeks to analyze patterns of health-related online information, such as search engine queries, to identify unmet needs. This study uses Google Keyword Planner to map spatial–temporal trends in interest, awareness, and unmet information needs for rare dermatological diseases. This article can be accessed here: www.doi.org/10.2196/69040

Conversational AI and chatbots (Appendix 1)
A systematic overview of the field of chatbots in history-taking in medicine is compiling the evidence (52). The focus is on their applicability, disadvantages, and ethical considerations in different clinical settings and dermatology.
This article can be accessed here: www.doi.org/10.2196/56628

Hybrid care in dermatology (Appendix 2)
This paper analyzes the role of hybrid care, which consists of a digital consultation and an in-person consultation (53). This article can be accessed here: www.doi.org/10.1002/hsr2.2241

2.3.2 Research objectives

The overall objective of this cumulative thesis is to provide empirical insights into the use of digital tools to support dermatology and public health.

The studies included are characterized by diverse designs and objectives, but overlap in their thematic focus and overarching aims:

- To uncover the acceptance and perceived usefulness of digital health tools in chronic inflammatory skin diseases
- To assess their acceptance, willingness to use, and perceived usefulness regarding technological tools such as telemedicine, wearables, and chatbots
- To examine the digital behavior profiles and digital health behavior patterns of the general population to identify trends and knowledge gaps related to diseases (infodemiology)
- To collect the practical implications for integrating digital innovations into clinical practice and healthcare systems and develop evidence-based recommendations for inclusive, data-driven, and patient-centered dermatology.

Each publication pursues these interrelated goals with unique approaches, tailored methods, and target groups. Together, they form a coherent research concept focusing on practical relevance and interdisciplinary thinking for new research approaches and innovative insights.

2.3.3 Contribution to public health and digital medicine

By bringing together the results of six peer-reviewed publications, this work contributes to ongoing efforts to promote digital, patient-centered, and data-driven practice in public health and dermatology. The studies included herein provide solid evidence that digital access can be improved and inequalities in care reduced by taking telemedicine and online services to the next level. They contribute to developing less reactive health technologies by identifying key drivers and barriers to adoption. The dissertation also makes a methodological contribution to innovation in dermatological research using infodemiology. It highlights the importance of digital literacy, user-centered design, and ethical considerations in using AI and chatbot systems in future healthcare.

By expanding their contributions, they are supporting the convergence of clinical dermatology, digital medicine, and public health while also contributing to further developing the conceptual and empirical foundations for future digital interventions in terms of access, engagement, and health outcomes for patients with chronic and rare diseases.

2.4 Methodological overview

The six articles in this cumulative dissertation cover a wide range of empirical research methods and reflect the complexity of digital innovations using dermatology as an example. This chapter describes the methods used in three primary types of research: quantitative surveys, long-term observations with multiple measurement points, and a systematic literature review for a holistic view of the currently available evidence and infodemiology (based on Internet search behavior and its qualitative contexts). Despite the methodological diversity, all have a common focus on practical relevance, user-centered design, and ethical integrity. Cross-sectional surveys were used to quantify acceptance. Prospective telemedicine studies have been conducted to test feasibility, implementation, and investigate long-term effects. Infodemiology was used to understand social behavior patterns, and systematic reviews were used to support the assessment of the current literature and future potential of chatbots in healthcare.

2.4.1 Quantitative survey studies

Four articles in this cumulative dissertation were cross-sectional studies that examined attitudes to, acceptance of, and willingness to use digital health tools. One study investigated the feasibility and satisfaction with teledermatology among patients and dermatologists treating patients with CSU (49). User-friendliness, communication quality, and intention to use hybrid care models in the future were assessed. In addition, quality of life and disease progression were evaluated over more than one year. Another study examined the perspectives of patients and physicians regarding the perceived benefits and willingness to consider digital health services for the treatment of urticaria (48). Patients and physicians were presented with standardized and validated questionnaires. The focus was on technological readiness, digital literacy, and perceived barriers to adoption. Another study investigated the general acceptance of wearables in Germany (50). Participants were asked about their acceptance of health wearables for active monitoring, concerns about data security, and their attitudes toward continuous digital monitoring in a dermatological setting. The surveys were conducted using standardized questionnaires, where possible, with the help of validated measurement instruments. The research on acceptance was based on the Unified Theory of Acceptance and Use of Technology (UTAUT) (54). These models attempted to explain users' intentions and use of technologies, considering important prerequisites such as performance expectations, effort expectations, social influence, and framework conditions. In addition to UTAUT, other constructs from supporting theories—such as TAM (Technology Acceptance Model)—were also considered to define a solid conceptual framework for acceptance behavior in the field of digital health (55,56). User attitudes, perceived usefulness, ease of use, and behavioral intentions were measured using several Likert scales. The questionnaires were completed on paper or online. Descriptive statistics, subgroup comparisons, and multivariate regressions were used for statistical analysis to identify predictors of acceptance and actual use. All analyses, including graphics creation, were performed in R and SPSS. The specific packages are mentioned in the section: Data collection, analysis, and ethics.

2.4.2 Systematic literature review

A study used a systematic review approach to examine the state of evidence on chatbots for medical history-taking in clinical settings. Based on the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), peer-reviewed databases such as PubMed, Scopus, and Web of Science were searched using predefined Boolean search queries (57,58). Chatbot applications in healthcare focusing on medical history-taking were the primary inclusion criteria. Exclusion criteria were divided into non-clinical chatbots, opinion articles, and studies without empirical data. Two reviewers independently extracted data; disagreements were resolved through discussion. The reported findings focused on chatbot design, performance, user preferences, usability, and safety concerns.

2.4.3 Web search and infodemiology study

A further methodological approach focused on infodemiology and analyzed search engine queries to measure public interest in rare disease eosinophilic disorders. Infodemiology provides indirect and helpful information about collective human behavior that can complement traditional epidemiological data by delivering real-time, population-based metrics on shared interests and concerns. Google Ads keyword planner was used to examine search volumes in Germany between 2020 and 2023. The search terms were developed from medical terminology, patient forums, and expert consultations. Seasonal patterns, peaks of interest, and regional differences were identified using time series analysis and geographic mapping with R statistical software. The analyses included a descriptive analysis of the data, a decomposition of the time series (LOESS), tests for differences in proportions (chi-square), a Z-score fluctuation analysis, and correlations to identify temporal trends, seasonal patterns, and regional differences. Keyword trends were verified using data from Brandwatch. This method identified potential knowledge gaps and unmet information needs in the general population regarding rare diseases.

2.4.4 Data collection, analysis, and ethics

The data collection method varied depending on the type of study. When collecting digital questionnaire data, we used Research Electronic Data Capture (REDCap) (59,60).

All survey studies were approved by an institutional ethics committee, except for the systematic review and the crowdsourcing data study, which were based on secondary data. All participants gave their written consent. All data were anonymized or pseudonymized when multiple time points were measured.

Descriptive and inferential statistical methods using the software programs IBM SPSS Statistics 28 (IBM Corporation, Armonk, NY, USA) and R statistics (61) were used, as well as factor analysis for regression models to identify predictors of technology acceptance, thematic synthesis and evidence mapping in the systematic review, and time series models or spatial analyses in the infodemiology study (51). Likert-scale responses were visualized using the Likert R package (62), while alluvial diagrams illustrated categorical flows. Risk-of-bias assessments in the systematic review were visualized using robvis, and data wrangling was supported by dplyr and related tidyverse tools (63). For spatial and temporal analyses, we employed rnaturalearthhires, rnaturalearthdata, and ggplot2 (64–67). Time series decompositions were conducted using the classical decompose() and stl() functions (68). Web search trend validation was supported by the social listening platform Brandwatch. The analysis of missing data was performed using predefined imputation methods and sensitivity analyses. A multidisciplinary approach was adopted. This involved collaboration with clinicians, statisticians, digital health experts, public health experts, and digital service providers (e.g., close cooperation with telemedicine providers). All data and analyses followed the principle of FAIR (findable, accessible, interoperable, and reusable) whenever possible and were conducted by best academic practices regarding transparency and reproducibility (69).

2.5 Summary of included publications

2.5.1 Acceptance and Perceived Usefulness of Digital Health Services in the Management of Chronic Urticaria: A Survey of Patients and Physicians

The first article of this cumulative dissertation shows that acceptance, trust, and use of digital health services can vary greatly among patients and physicians, even though both groups view digital health services as beneficial for treating CU. It shows that 75.3% of physicians and 59.5% of patients consider digital solutions such as apps and video consultations beneficial. Still, only 30.6% of patients feel confident in making healthcare decisions based on information found online. The desire for technology was expressed more often by physicians, with 80.2% of physicians compared to 60.3% of patients stating that they were very curious (p = 0.002) about new technologies. More than half of patients used digital tools for health services, such as smartphones and internet platforms, but synchronous healthcare formats, such as video consultations, were rarely used (15%). The COVID-19 pandemic positively impacted digital openness, especially among physicians compared to patients (46.5% vs. 29.8%). Concerns included data protection and infrastructure issues, as well as a lack of awareness, costs, and a lack of evidence. Although digital health services are an option for caring for patients, most (68.6%) still prefer in-person care, underscoring the need for direct human contact in the care of chronically ill people.

2.5.2 Bridging the gap through telemedicine: Pilot study on the acceptance and use of teledermatology for urticaria

The second article of this cumulative dissertation is a 12-month prospective study on a structured digital care concept for patients with CSU. A telemedicine platform was used to offer video consultations every three months and enable long-term symptom control with electronic patient reports (ePROs), including an urticaria control test for symptom measurement, a dermatological quality of life index, and overall satisfaction (“happiness”). Acceptance of the digital concept among participating patients was high: 92% of participants reported that it could be a good alternative to in-person care, and 100% agreed that health issues could be discussed effectively via the platform. Physicians also agreed on its reliability, time savings, and clinical benefits. Disease control among the patients was maintained over time. The patients' quality of life in the study improved over the study period (DLQI, p = 0.04). There were only a few technical problems, mainly with the setup (e.g., spam filters for email invitations to register on the platform).

In summary, the study shows that teledermatology can be successfully integrated into the care of CSU patients and represents a flexible, patient-centered, and scalable care model. Through continuous monitoring, the concept can be added to standard care. It highlights the ability of digital health applications to improve long-term monitoring of chronic skin diseases and patient satisfaction.

2.5.3 Continuously monitoring the human machine? – A cross-sectional study to assess the acceptance of wearables in Germany

This cross-sectional analysis examines the acceptance, usage patterns, and perceived barriers to wearable health technologies in Germany. A total of 550 participants (average age: 36.6 years; 51.3% female) were included in the analysis, of whom 33.8% (n = 186) reported currently using wearables, namely smartwatches (61.6%) and fitness wristbands (30.4%). Patients reporting higher weekly physical activity (>4 hours/week: 46.1% ever used, p < 0.001), those living in urban areas (p = 0.037), and people with higher education (p = 0.045) used wearables more frequently. The most important factor for using wearables in the regression model was higher physical activity (PR = 1.913, 95% CI: 1.142–3.203, p = 0.001). Attitudes toward data sharing varied depending on the recipient: 61.5% would share data with healthcare providers, while 42.7% would do so anonymously with manufacturers. Interest in wearing future health monitoring devices was high; 57.8% of men and 63.3% of women were open to wearing a sensor patch for monitoring their health. Implants were less accepted (men: 20.0%, women: 12.8%). Common barriers to use were lack of perceived benefit (50.5%), high cost (16.2%), and privacy concerns (9.9%). Reliability measures for acceptance structures based on TAM and UTAUT were achieved with moderate stability (Cronbach's α: perceived usefulness = 0.798; intention to use = 0.62). This study underscores the high level of acceptance of wearables. It shows that implementing new innovative sensor-based health monitoring in routine care is promising, if issues regarding user-friendliness, proof of benefit, and data security are resolved.

2.5.4 Tracking Public Interest in Rare Diseases and Eosinophilic Disorders in Germany: Web Search Analysis

Hypereosinophilic syndrome (HES) and related eosinophilic disorders are relatively rare but dermatologically important clinical entities that may be associated with pruritus, urticarial rashes, and eosinophilic skin infiltrates. The present study is part of a broader effort to better understand how patients search for information about rare diseases with dermatological manifestations. To this end, infodemiological approaches were used to estimate the German public's interest in eosinophilic diseases, considering Google search volumes from 2020 to 2023. 178 medically relevant terms were examined using the Google Ads Keyword Planner, generating 1,745,540 search terms. The most frequently searched term was the misspelled “Eosophile” (274,560 searches). This highlights a significant gap in digital health literacy and suggests that patients often resort to phonetic approximations when searching for complex medical terms. This was followed by “eosinophilia” (107,840) and “HES” (95,100), etc. Most searches were for “eosinophilia,” “eosinophiles,” and “Churg–Strauss syndrome”. Diagnosis-related searches accounted for more than 13% of all searches, indicating a clear interest in interpreting symptoms and self-diagnosis. Searches increased over the years, peaking in January 2023 with 49,320 queries. There were clear seasonal trends and regional differences, with Hamburg (highest per capita interest) and Bad Bramstedt showing the highest values and Bremen and Saxony-Anhalt showing the lowest values. The results indicate growing public interest in eosinophilic diseases and reveal a specific need for information. This study highlights the usefulness of web search data for monitoring rare diseases and the potential of infodemiology for targeted health communication and initiatives to promote digital literacy in dermatology and public health.

2.5.5 Transforming Health Care Through Chatbots for Medical History-Taking and Future Directions: Comprehensive Systematic Review (Appendix)

This systematic review examined 18 studies (15 observational studies, 3 RCTs) that evaluated chatbot-based medical history-taking in various clinical areas (dermatology, oncology, genetics, and mental health). The documentation efficiency of chatbots in the included studies was partially confirmed, with time savings of up to 57.3% and a usability rating of up to 96/100. Depending on the context, diagnostic agreement with physicians varied between 51% and 69%. However, limitations included the low quality of the studies, low trust in chatbot systems, and difficulties in implementing them into the clinical workflow. 38% of observational studies adhered to high-quality methodology, but the ability to query structured data such as family history was a unique strength of chatbots. Chatbots certainly have potential as a complementary resource for standard data collection and pre-consultation triage in low-resource settings. Future studies must address rigorous validation, emotional intelligence, and ethical practice to enable safe and effective use in clinical contexts, with particular attention to data privacy, security, and compliance with relevant regulations (e.g., GDPR).

2.5.6 Hybrid care potential of teledermatology: The importance of linking digital and physical practice and acceptance of online services: A cross-sectional study (Appendix)

This was a cross-sectional analysis of the use of a store-and-forward teledermatology platform in Germany between July 2022 and March 2023. A total of 1,141 people participated, most of whom had not seen a dermatologist for at least one year. Common reasons for using the platform were long waiting times and the lack of availability of appointments for in-person consultations. Although 77.6% were willing to try teledermatology as their first choice for future skin conditions, the ability to see a physician in person was particularly valued by older adults and people in rural areas. Younger age, living in an urban area, and satisfaction with previous digital consultations were significantly associated with higher acceptance of teledermatology. This study highlights the potential of store-and-forward teledermatology for promoting access to dermatological care. It re-emphasizes the need for hybrid models seamlessly combining digital care with in-person visits.

2.6 Synthesis of evidence across studies

This cumulative dissertation summarizes the results of six empirical studies on the transformative potential of digital health technologies in dermatology, focusing on patient-centered care, systemic challenges, and implications for public health.

First, the studies collectively emphasize digital tools' broad but uneven acceptance among patients and healthcare providers. Telemedicine, wearables, and chatbots are promising and efficient, but their practical use is still limited due to digital literacy, inadequate infrastructure, data security, and legal uncertainties. For example, teledermatology has been widely accepted by urticaria patients and healthcare providers (92% and 100% respectively). At the same time, technologies such as chatbots and wearables have been met with trust issues and varying willingness to use.

Second, the results show that willingness to use digital health services is context-specific and influenced by demographic, regional, behavioral, and attitudinal characteristics. There was consistent evidence that younger age, urban residence, greater physical activity, and positive experiences with digital consultations were associated with greater openness and willingness to use digital services. This suggests an “all-or-nothing” approach may not meet dermatology patients’ diverse needs and capabilities.

Third, the results suggest that digital solutions can play an essential role in closing gaps in care, particularly for chronic and rare diseases. The data on eosinophilic diseases revealed information gaps and many search queries for diagnosis, suggesting a limited focus on rare diseases in traditional health information. This argues in favor of digital tools that can be used for clinical management and to guide public health interventions.

Fourth, the contributions underscore the relevance of hybrid models that combine the potential of digital innovations with the still irreplaceable importance of physical contact. In all studies, participants emphasized that digital solutions are convenient, trust and safety are best built through face-to-face interactions. This points to a potential model for the future of dermatology that leverages technology while maintaining human relationships.

Finally, the work contributes to the methodological and conceptual advancement of digital dermatology and public health by incorporating acceptance models (e.g., UTAUT—a framework explaining technology use based on performance and effort expectancy; and TAM—a model focusing on perceived usefulness and ease of use), patient-reported outcomes, and data on real-world behavior. It calls for further work on ethical, regulatory, and structural prerequisites for implementation and emphasizes the importance of stakeholder involvement and evidence-based design to ensure sustainable acceptance. Overall, this integrated synthesis confirms that digital health tools in dermatology are technically feasible and socially necessary. Their effective use will depend on trust, user-friendliness, and systemic adaptation that support a fairer, more responsive, and more digital future for dermatological health.

2.7 Implications for stakeholders

The results of this manuscript are of practical relevance to all stakeholders involved in healthcare digitization. In clinical dermatology, integrating telemedicine platforms, wearables/devices, and patient-reported outcomes offers a real opportunity to advance continuity of care, disease tracking, and individualized therapeutic approaches. For public health institutions, the studies provide a model for better integration of information sources—such as digital information processing (infodemiology) and complex surveillance systems—to better understand patients' behavior and trends in patient behavior, including patient needs and information-seeking patterns, particularly in regard to rare or insufficiently studied skin disorders. Technology developers receive much-needed guidance on user-centered design, trust-building, and interoperability, including highlighting the importance of co-creation and iterative validation to ensure that digital innovations are based on clinical reality and patient choice. For the policy agenda, the findings underscore the need to align reimbursement models, regulatory pathways, and the integration of digital technologies into national care strategies to ensure equitable access and sustainable uptake. Taken together, these implications contribute to a more comprehensive picture of a digitally enhanced, patient-centered, and adaptable healthcare system.

2.8 Scientific contribution

This compilation provides new empirical, conceptual, and methodological contributions to the emerging field of digital dermatology and public health. The six studies presented cover various aspects of the digital revolution, including patient and physician acceptance and the population's information-seeking behavior in the field of dermatology. Together, they form an interdisciplinary and evidence-based foundation for the use of digital tools in routine clinical care and health system interventions.

The most important scientific contributions are:

Empirical evidence of acceptance and use

The dissertation provides comprehensive insights into how patients and providers accept and perceive the benefits of digital health services such as telemedicine, wearables, and chatbots, as well as the barriers they see to using such services. Using established acceptance models (e.g., UTAUT, TAM) and stratified analyses, factors in and barriers to digital acceptance in dermatology are measured.

Realistic evaluation of digital interventions

The dissertation provides evidence of the feasibility, clinical added value, and high acceptance of teledermatology and hybrid care models (in cross-sectional and prospective studies). These observations are important for translating these digital programs into sustainable healthcare.

Infodemiological perspective on population behavior

The analysis of web search data provides population-level insights into digital health literacy, unmet information needs, and temporal and geographic benchmarks of interest in diseases. This is a methodological advance and highlights the importance of digital epidemiology in dermatological research.

Systematic evidence mapping

The systematic review of chatbots for medical history-taking has critically assessed the state of the evidence and highlighted the potential and limitations of a big new era and their use in healthcare. This sets a research agenda for development and further validation.

Methodological quality and integrative progress

The work integrates the fields of dermatology, public health, medical informatics, and behavioral sciences. In addition, methodological standards are improved by incorporating ethics, real-world data analysis, and patient-reported outcomes into a framework that encompasses quantitative, qualitative, and infodemographic/cartographic approaches.

Strategic implications for stakeholders

The dissertation highlights that implementation science and coordination between stakeholders in the health and healthcare industry are important and that the influence of stakeholders in health research varies.

In summary, this work contributes to digital medicine by showing that dermatological care can be effectively improved with digital tools and that public health research can benefit from digital data sources. It promotes future innovation and the expansion and integration of digital health strategies in dermatology and other fields.

2.9 Limitations and future directions

Although this study makes an important contribution to the topic of digital tools in dermatology, it also has limitations. Causal conclusions were only possible to a limited extent, as most of the studies included were cross-sectional studies. Although the sample sizes were sufficient for preliminary conclusions, they may not have reflected the full spectrum of patient experiences across different sociodemographic or geographic groups. Furthermore, the acceleration of digital change could mean that some of the research findings are already outdated before publication. Further research is recommended to evaluate the long-term impact of digital interventions on medical outcomes and patient behavior. In addition, attention must be paid to achieving digital equity by reducing inequalities in access, digital literacy, and infrastructure. Finally, the successful integration of digital tools for healthcare into the current healthcare system requires the involvement and commitment of all stakeholders, as well as continuous evaluation to ensure that innovation leads to sustainable care.

2.10 Conclusion

This cumulative dissertation reports on findings from various perspectives, which are summarized here. The survey on the acceptance of digital health services (Paper I) showed that physicians and patients had positive attitudes toward digital health services, but only one-third of patients felt comfortable making decisions based on information from the Internet (48). The 12-month pilot study on teledermatology (Paper II) showed high acceptance rates regarding effectiveness, including stable disease control and quality of life. The pilot study has thus demonstrated the potential for a Germany-wide study with more than 20 study centers, which is currently being conducted. In the wearables study (Paper III), one-third of participants had already worn a wearable device, with most participants reporting clear benefits from using the device. The main obstacles reported were the perceived benefits, the costs, and data protection (50). The infodemiology analysis (Paper IV) revealed high search volumes for phonetic approximations (misspellings of eosinophile) of eosinophilic diseases with clear seasonal and regional differences, indicating a significant lack of information (51). The evaluations of chatbots (Paper V) identified effects in terms of time savings and structural potential but pointed to the poor methodological quality of the studies and problems with trust and integration (52). The study on hybrid care offerings (Paper VI) found that three-quarters of respondents rated teledermatology positively overall, but continued to consider in-person consultations important, especially older patients and patients in rural areas (53).

All these results paint an overall picture: there is general openness to digital health services, teleconsultations, wearables, and chatbot-supported tools, but actual usage remains limited as long as trust, strong evidence, and smooth integration are lacking. The reported acceptance highlights the potential, but also that the prospects do not necessarily lead to routine use. Some of the technical problems encountered in the pilot phase (e.g., obstacles to registration on digital platforms) can be easily resolved, but other obstacles (data security, costs, evidence) require more complex measures. The results also confirm that internet-based analyses can identify major gaps in knowledge about rare diseases. This underscores the urgency of implementing communication plans in the field of public health and developing patient-oriented information systems that meet the needs of these vulnerable population groups by making health information more accessible, relevant, and trustworthy. Methodologically, the integration of surveys, a prospective pilot study, infodemiology, and a systematic review enabled a comprehensive analysis: It addressed aspects at the micro level (acceptance, trust, user satisfaction) and the macro level (information-seeking behavior of the population, systemic infrastructure barriers). The integration of technical, clinical, and health policy perspectives required interdisciplinary collaboration.

From a practical perspective, these considerations suggest that digital dermatology solutions need to be developed that meet user needs and can be integrated into the workflow. As mentioned above, teleconsultations should be a complementary rather than a replacement modality. Wearables and chatbots require clear documentation of their benefits in healthcare, robust solutions for data protection and interoperability, and aggregated evidence. Infodemiological approaches can be a good way to identify information gaps early on and improve digital health literacy. At the organizational level, scaling up pilot projects to larger nationwide projects requires training for providers, flexible reimbursement models, and clear regulatory frameworks. From a scientific perspective, prospective multicenter studies and studies using mixed methods are needed to accurately quantify the long-term clinical, psychosocial, and economic impacts of digital interventions. In addition, standardized requirements for the validation and ethical review of new technologies (chatbots, AI systems, etc.) and measures to ensure digital equity are further important steps.

Building on the findings of this cumulative dissertation, future research should investigate the long-term impact of digital interventions on outcomes reported by patients or study participants, particularly in underrepresented or rare disease groups. In addition, the creation of interoperable systems developed in collaboration with patients and healthcare providers will be critical to translating acceptance into sustainable routine use. Finally, policy and financial mechanisms must be further developed to support a digital transformation that balances ethical considerations, the protection of personal health data, and health equity.

3. Papers

3.1 Paper I

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BMC Health Services Research

RESEARCH **Open Access**

Acceptance and perceived usefulness of digital health services in the management of chronic urticaria: a survey of patients and physicians

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Abstract

Background Chronic urticaria (CU) is a complex and unpredictable skin condition that significantly affects patients' quality of life. As the healthcare landscape increasingly integrates digital health technologies, understanding their perceived usefulness in CU management from both patient and physician perspectives is crucial.

Objective This study investigates the acceptance, perceived usefulness, and potential barriers to using digital health services, such as medical apps and video consultations, among patients with CU and their healthcare providers.

Methods A quantitative survey was conducted across multiple specialized centers, specialist clinics, and general practices, involving both patients and physicians. The study utilized standardized questionnaires to assess digital health literacy, technology readiness, and attitudes toward adopting digital health services in CU management. Descriptive and inferential statistics, including Fisher's exact test, were employed to analyze the data.

Results A substantial proportion of the 121 surveyed patients and 101 physicians perceived digital health technologies as beneficial in managing CU, with 59.5% of patients and 75.3% of physicians agreeing on their advantages. However, 21.5% of patients and 14.9% of physicians remained neutral, while 8.3% of patients and 4.0% of physicians found these technologies unhelpful. Key barriers to adoption were identified, including concerns over data privacy, limitations in technical infrastructure, and a lack of awareness of available digital health solutions.

Conclusion While many patients and physicians recognize the potential of digital health technology to improve urticaria management, some remain uncertain or skeptical. Addressing concerns and improving digital understanding is critical to the future implementation and integration of these technologies into care. Due to the cross-sectional design of the study and the self-reported data, further research may be needed to confirm these results.

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Keywords Chronic urticaria, Dermatology, Digital health, User perspectives, Technology acceptance, Barriers to adoption

Summary box

What is already known on this topic

- Digital health services (DHS), such as medical apps and video consultations, have the potential to enhance disease management in chronic conditions like chronic urticaria (CU).
- Acceptance and adoption of DHS vary significantly, with healthcare providers generally showing higher enthusiasm compared to patients.
- Barriers such as data privacy concerns, technical infrastructure, and low digital health literacy impede the broader adoption of DHS.

What this study adds

- This cross-sectional study highlights that while most patients and physicians perceive DHS as beneficial for CU management, physicians exhibit significantly higher readiness and enthusiasm for technology adoption.
- The study identifies specific barriers to adoption, including patients' low confidence in decision-making based on digital health information and physicians' concerns about cost and insufficient evidence of efficacy.
- Patients show a preference for synchronous communication (e.g., video consultations) but still value traditional in-person appointments, especially for first consultations or emergencies.

How this study might affect research, practice or policy

- The findings underscore the need for targeted strategies to improve digital health literacy among patients and enhance their confidence in using DHS effectively.
- Policymakers and healthcare providers should focus on robust data protection measures and evidence-based promotion of DHS to address both patients' and physicians' concerns.
- Integrating DHS into CU care requires balancing technological efficiency with the need for personal interaction to ensure patient-centered care.

Introduction

Chronic urticaria is a skin disease characterized by the appearance of itchy wheals or hives. Angioedema also occurs in up to 40% of cases [1–4]. We speak of chronic urticaria when the disease lasts longer than 6 weeks. One of the biggest challenges with chronic urticaria is that flare-ups can occur very quickly and unpredictably. These flare-ups can be a significant burden for sufferers. This disease significantly impairs the quality of life and productivity of patients with chronic urticaria and leads to more absences from work [2, 5].

Urticaria can lead to sleep problems, difficulties in everyday activities, and a strong increase in anxiety and stress [6–8]. Angioedema is swelling of the skin that may affect the skin surface or deeper skin layers and mucous membranes. There may be rapid and unpredictable swelling. This can cause a feeling of suffocation [8–10].

This type of swelling occurs in about 40% of people with urticaria [11]. Up to 67% of people with CU have both angioedema and wheals at the same time [12]. For this reason, the guideline-based treatment of urticaria includes a specific escalation algorithm to achieve complete symptom control [4]. A large global observational study (AWARE) has shown that people with antihistamine-refractory CU often have uncontrolled symptoms, are prone to angioedema or even comorbid chronic induced urticaria, and their quality of life is severely affected, relying on many medical resources [13]. Despite clear guideline recommendations, AWARE revealed that only a minority of patients receive appropriate escalation therapy, with many remaining on ineffective treatments for prolonged periods. Another important study, ASSURE-CSU, highlighted the substantial economic and humanistic burden of CSU, demonstrating that undertreatment not only leads to increased healthcare utilization but also significantly impacts work productivity and daily functioning. Other studies have reported that there is a pattern of undertreatment and that guidelines are not properly followed [3, 7, 14, 15].

Treatment of CU usually requires an interdisciplinary team. Dermatologists and general practitioners are crucial, but sometimes, depending on the situation, specialists from other fields such as allergy are also needed [3]. The diagnostic process can be quite involved. Therefore, it is often better for patients to contact specialized centers or clinics that combine all the necessary expertise. Patients themselves can contribute to a timely diagnosis by documenting the course of the disease, therapies, skin changes, nutrition, etc. in a urticaria diary (including photo documentation). Such documentation, such as a urticaria diary (and possibly photos), can be very helpful in diagnosing and treating the disease [16–20].

Despite the existence of specialized UCARE centers and various participation opportunities in the diagnostic and therapeutic process, achieving a timely diagnosis and optimal symptom control remains challenging due to the unpredictable nature of CU, which significantly burdens the affected individuals [7]. This situation presents numerous opportunities for the implementation of digital health services in CU management [21, 22]. The newest innovative approaches using digital tools, including teledermatology, mobile health apps, and remote monitoring tools like wearables or chatbots, could improve access to care and support self-management [23–26]. Studies show that teledermatology reduces travel burdens and enhances timely medical advice, while CU tracking apps improve physician-patient communication [18–20, 27]. Before these concepts can be implemented in real world practice, it is essential to assess the willingness of patients and physicians. The opportunities and obstacles associated with these implementations must be thoroughly analyzed.

Objectives

This study aims to assess the level of acceptance of digital health services among CU patients and healthcare providers. It also seeks to identify which digital health services are currently being utilized in CU management and to determine the specific areas of care where these services are applied. Furthermore, the study explores the opportunities and barriers experienced by both healthcare providers and patients in using digital health services to manage CU.

Methods

Study design

This study was designed as a cross-sectional survey to evaluate the acceptance, perceived usefulness, and barriers to using digital health services in managing CU.

Setting

The study was conducted across multiple outpatient clinics and practices in Germany specializing in CU management. These included dermatology practices, specialized urticaria centers (UCARE centers), and general medical practices. The recruitment and data collection phases took place over a specified period from February 2023 to November 2023.

Participants

Patients eligible for inclusion were individuals aged 18 years or older who had already been diagnosed with CU by a specialist, either a dermatologist or an allergist/immunologist, prior to their participation in the study. Healthcare providers included in the study were dermatologists, general practitioners, and assistant physicians who were actively involved in the management of chronic urticaria (CU). While we did not specifically assess formal training in CU management, all participating physicians had direct experience in managing CU patients. Additionally, we collected demographic data on physicians, including age, to examine potential variations in responses based on age. Our subgroup analysis did not reveal significant differences in responses due to the age of the physicians. We performed a stratified analysis based on the number of patients treated per physician, and no significant differences were found regarding digital health service use. Exclusion criteria included patients without a confirmed urticaria diagnosis, individuals without proficiency in German, minors, and healthcare providers not directly involved in urticaria care. Participants were recruited from specialized urticaria centers, dermatology practices, and general medical practices. Participants completed the questionnaires individually in a controlled, private setting, either in their healthcare provider's office or a designated area within the clinic, to minimize any external influence.

Variables

The primary variables included participants' attitudes toward digital health services, frequency of use, and perceived barriers to adoption. We also assessed the impact of COVID-19 on digital health service utilization. CU was defined according to EAACI guidelines as the appearance of wheals, angioedema, or both, lasting more than six weeks [4]. Demographic data such as age, gender, place of residence, and income were collected. Place of residence was categorized into five groups: large city (> 100,000), medium city (20,000–100,000), small town (5,000–20,000), rural area (< 5,000), and million city (> 1,000,000). Income was grouped into less than €2,500, between €2,500 and €5,000, and more than €5,000. We also measured technology readiness and digital health literacy using the G-eHEALS scale, a validated instrument for assessing individuals' ability to seek, appraise, and apply health information from digital sources. The G-eHEALS captures key dimensions of eHealth literacy, including confidence in navigating online health resources and evaluating their credibility. Additionally, we examined the perceived impact of digital services on the doctor-patient relationship, care quality, and changes in usage due to the COVID-19 pandemic [28, 29].

Data sources and measurement

The self-developed questionnaire was first tested in a pilot study to assess clarity, reliability, and validity. A diverse sample of nine participants, comprising five patients and four physicians, provided feedback to ensure representation of both patient and healthcare provider perspectives. The gender distribution of participants was 3 male and 6 female. Participants were asked to complete the questionnaire and comment on item wording, comprehension, and overall structure. Based on their feedback, minor adjustments were made to enhance the clarity of certain questions and improve response options where needed. Data were collected from both patients and healthcare providers using two standardized questionnaires. The patient questionnaire assessed digital health literacy, employing the G-eHEALS scale, and technology readiness, using an adaptation from the Technology Acceptance Model 2. The physician questionnaire similarly examined the professional use and perceptions of digital health services. Both questionnaires used Likert scales for response measurement and dichotomous options for specific behaviors. To ensure comparability between patients and physicians, the questionnaires included parallel items addressing technology readiness and digital service utilization.

Bias

Efforts to mitigate bias included the use of standardized and validated questionnaires. Sensitivity analyses were performed to evaluate the impact of missing data and potential variations in responses across different demographic groups, further ensuring the reliability of the findings.

Quantitative variables

In this study, quantitative variables were derived from standardized questionnaires that captured various aspects of digital health service utilization and attitudes toward digital technologies. Key variables include technology readiness, digital health literacy, frequency of digital health service usage, and perceived impact on the doctor-patient relationship and quality of care. Responses were measured using Likert scales and dichotomous choices to assess agreement levels and behaviors. Socio-demographic data, such as age, gender, and professional background, were also collected to inform subgroup analyses.

Statistical methods

Descriptive statistics were used to summarize the demographic and baseline characteristics of the participants. Categorical variables were presented as frequencies and percentages. For continuous variables, mean values and standard deviations were calculated. Group comparisons were performed using chi-square or Fisher's exact tests for categorical variables and independent t-tests or Mann-Whitney U tests for continuous variables. Statistical significance was defined as a p-value of less than 0.05.

Data analysis was performed using R Statistical Software (Version 2023.06.2; R Core Team, 2023). The analysis involved key packages such as dplyr [30] for data manipulation, Likert [31], and ggplot2 [32] for data visualization, and appropriate statistical testing functions available within base R.

Subgroup analysis

Subgroup analyses were conducted to explore potential differences in responses based on demographic factors, such as age, gender, and professional role (e.g., dermatologists versus general practitioners). The relationship between technology readiness and digital health service utilization was also examined across subgroups to identify trends and variations. These analyses aimed to provide a more granular understanding of how specific groups perceive and interact with digital health services.

Another subgroup analysis (Fig. 1) revealed that patients predominantly used digital apps rather than video consultations. This is consistent with data from another study [21], which also showed higher usage of apps compared to video consultations. This pattern may reflect a genuine preference for in-person visits, but it could also be due to the current lack of a dedicated digital platform for urticaria care. In another study, we implemented and evaluated a digital platform for urticaria and demonstrated that remote monitoring via patient-reported outcomes is feasible [26]. Furthermore, our recent systematic review on chatbots for medical history-taking [23] underscores the transformative potential of digital tools to streamline clinical workflows and enhance patient engagement, reinforcing the need for dedicated digital platforms.

In this study, missing data were handled by including only observations where at least 80% of the data were complete. Observations with more than 20% of missing data were excluded from the analysis to maintain the robustness and reliability of the findings.

Sensitivity analyses tested the robustness of findings by exploring response variations based on key demographics like age and gender. Two approaches addressed uncertain responses: first, by grouping 'Agree/Strongly Agree (including Neutral)' to capture broader acceptance, and second, by excluding neutral responses to focus on clear agreement or disagreement.

Results

Participant characteristics

A total of 121 patients with CU and 101 physicians participated in the study (Tables 1 and 2). The median age of patients was 40.5 years (SD = 15.1), with 64.5% (78/121) identifying as female, 18.2% (22/121) as male, and 16.5% (20/121) not providing a gender. Among physicians, the median age was 36 years (SD = 12.8), with 56.4% (57/101) identifying as female, 34.7% (35/101) as male, 1.0% (1/101) as diverse, and 7.9% (8/101) not providing a gender. A significant difference in gender distribution was observed between patients and physicians ($p = 0.0179$).

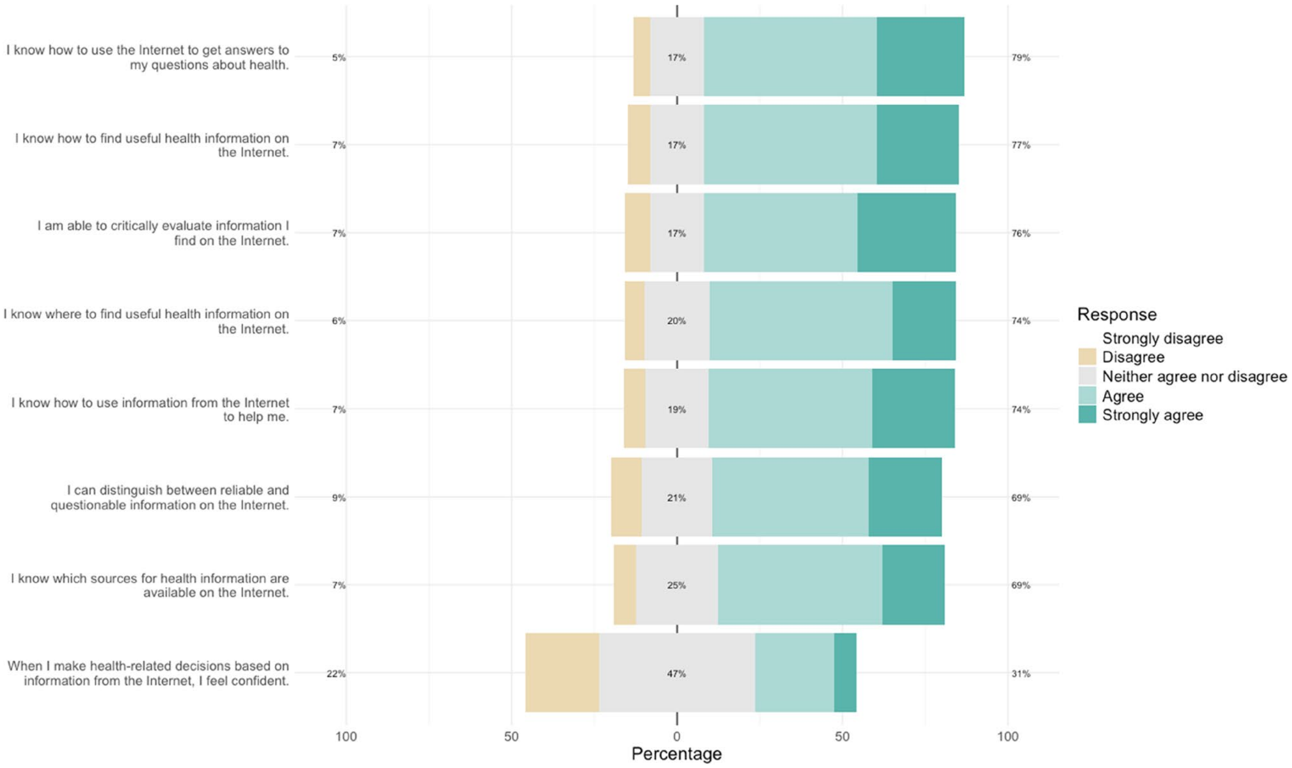

Fig. 1 Devices, media, and health services used or offered in urticaria care (Patients $n = 121$; Physicians $n = 101$): This figure shows the percentage of patients (blue) and physicians (orange) using or offering digital tools for urticaria care. Smartphones, the Internet, and email were most used, while video consultations and digital health applications (DiGA) were less common. Physicians more frequently engaged in self-administered blood sampling and online pharmacies

Digital health literacy and technology readiness

Most of the patients demonstrated moderate or higher levels of digital health literacy (Fig. 1), according to the eHealth Literacy Scale (eHEALS). Specifically, 7.4% of patients (9/121) fell into the “Low” category, 64.5% (78/121) were in the “Moderate” category, and 28.1% (34/121) were classified as having “High” eHealth literacy (Table 1). This indicates that 71.9% (87/121) of patients exhibited at least a moderate ability to find and use health information online. Over 75% (93/121) of patients knew how to use the Internet to find health-related information. However, only 30.6% (37/121) felt confident making health decisions based on online information.

Physicians showed greater enthusiasm for technological innovations than patients (Table 3). Specifically, 80.2% (81/101) of physicians were very curious about new technologies compared to 60.3% (73/121) of patients ($p = 0.002$), and 55.4% (56/101) of physicians desired to use technological products more frequently versus 27.3% (33/121) of patients ($p < 0.001$).

Attitudes toward digital health services

Regarding the usefulness of digital health services in managing urticaria, 59.5% (72/121) of patients and 75.3% (76/101) of physicians agreed or strongly agreed (Table 4). While 59.5% of patients and 75.3% of physicians agreed on the usefulness of these services, no significant demographic differences were observed in patient attitudes across age, gender, education, or place of residence (Table 5). However, patients from smaller towns and rural areas tended to show higher agreement rates compared to those from larger cities. While physicians showed a higher tendency to view these services favorably, the difference was not statistically significant ($p = 0.091$). Among patients, 21.5% (26/121) were neutral, and 8.3% (10/121) disagreed.

The COVID-19 pandemic positively influenced attitudes toward digital health services. Among patients, 29.8% (36/121) reported a more favorable view due to the pandemic, compared to 46.5% (47/101) of physicians ($p = 0.049$). Approximately one-third of both groups reported increased use of digital health services since COVID-19: 31.4% (38/121) of patients and 33.7% (34/101) of physicians.

Usage of digital health services

Current usage patterns (Fig. 1) revealed that 51.2% of patients (62/121) used smartphones for urticaria care, and 56.2% (68/121) utilized the Internet. Physicians offered services involving smartphones and the Internet at rates of 43.6% (44/101) and 51.5% (52/101),

Table 1 Demographics

Category	**Patients *n* = 121 Frequency (%)**	**Physicians *n* = 101 Frequency (%)**
Age Category		
Under 30	18 (14.9)	9 (8.9)
30–39	28 (23.1)	37 (36.6)
40–49	12 (9.9)	15 (14.9)
50–59	25 (20.7)	10 (9.9)
60 and above	11 (9.1)	13 (12.9)
Missing	27 (22.3)	17 (16.8)
Median Age (SD)	40.5 (15.1)	36 (12.8)
Gender		
Diverse	1 (0.8)	1 (1.0)
Male	22 (18.2)	35 (34.7)
Female	78 (64.5)	57 (56.4)
Missing	20 (16.5)	8 (7.9)
Educational Status		
I am still a student	5 (4.1)	-
I am still in vocational training	5 (4.1)	-
Without vocational training completion	2 (1.7)	-
Completion of vocational training of at least one year	37 (30.6)	-
University degree	49 (40.5)	-
Missing	23 (19.0)	-
Place of Residence		
Large City (> 100,000)	17 (14.0)	-
Small Town (5,000–20,000)	21 (17.4)	-
Rural Area (< 5,000)	21 (17.4)	-
Million City (> 1,000,000)	22 (18.2)	-
Medium City (20,000–100,000)	19 (15.7)	-
Missing	21 (17.4)	-
Income		
Up to 850 Euro	7 (5.8)	-
851–1,500 Euro	9 (7.4)	-
1,501–2,000 Euro	11 (9.1)	-
2,001–2,750 Euro	25 (20.7)	-
2,751–3,500 Euro	19 (15.7)	-
3,501–5,000 Euro	12 (9.9)	-
5,001–10,000 Euro	5 (4.1)	-
More than 10,000 Euro	0 (0.0)	-
Missing	33 (27.3)	-
eHEALS		
Low (< =20)	9 (7.4)	-
Moderate (21–32)	78 (64.5)	-
High (> 32)	34 (28.1)	-
eHEALS questionnaire (Agreement)		
I know which sources of health information are available on the Internet. (Missing 4)	83 (68.6)	-
I know where to find useful health information on the Internet. (Missing 3)	90 (74.4)	-
I know how to find useful health information on the Internet. (Missing 4)	93 (76.9)	-
I know how to use the Internet to find answers to my health-related questions. (Missing 3)	95 (78.5)	-
I know how to use information from the Internet in a way that helps me. (Missing 0)	90 (74.4)	-
I am able to critically evaluate information I find on the Internet. (Missing 0)	92 (76.0)	-
I can distinguish between reliable and questionable information on the Internet. (Missing 1)	84 (69.4)	-
When making health-related decisions based on information from the Internet, I feel confident. (Missing 6)	37 (30.6)	-

Table 2 Physicians' characteristics

Professional activity	Physicians $n = 101$ Frequency (%)
Assistant Physician (Other Hospital)	5 (5.0)
Assistant Physician (Private Practice)	7 (6.9)
Assistant Physician (University Hospital)	23 (22.8)
General Practitioner (Private Practice)	10 (9.9)
Dermatologist (Other Hospital)	4 (4.0)
Dermatologist (Private Practice)	24 (23.8)
Dermatologist (University Hospital)	18 (17.8)
Other	2 (2.0)
Missing	8 (7.9)
How many patients do you treat on average per quarter?	
up to 500	22 (21.8%)
500 to 1,500	35 (34.6%)
more than 1,500	27 (26.7%)
Missing	17 (16.8%)
How many patients with urticaria do you treat on average per quarter?	
0–10	41 (40.6%)
11–50	21 (20.8%)
51–200	18 (17.8%)
> 200	2 (2.0%)
Missing	19 (18.8%)
Do you think your patients (urticaria treatment) find digital health services useful?	
I don't know	24 (24.8)
Yes	59 (63.4)
No	10 (10.8)
N/A	8 (7.9)

respectively. Physicians expressed a higher intention to adopt digital health applications ("DiGA" in Germany) in the future compared to patients, with 24.8% (25/101) of physicians and 10.7% (13/121) of patients expressing interest ($p = 0.0071$). Video consultations were currently used by about 15% of both groups, with physicians having a higher rate of offering them before COVID-19 (18.8% [19/101] vs. 5.0% [6/121] of patients, $p = 0.0013$).

Perceived impact of digitalization on care and preferences for video consultations

Regarding the doctor-patient relationship, 31.4% of patients (38/121) and 40.6% of physicians (41/101) perceived digitalization as having a positive or very positive impact (Table 6). Concerning the quality of care, 40.5% of patients (49/121) and 56.5% of physicians (57/101) believed digitalization had a positive effect. For future use of video consultations, 36.4% of patients (44/121) were willing to use them for follow-up appointments, and 18.2% (22/121) for first appointments. Physicians were more inclined to offer video consultations for follow-ups (51.5%, 52/101) but less so for emergencies compared to patients.

Advantages and barriers of digital health services

Both groups recognized advantages (Fig. 2) such as location-independent use and increased flexibility. Physicians more frequently cited benefits like detailed documentation of the disease course (40.6% [41/101] vs. 14.0% [17/121] of patients, $p < 0.001$) and better preparation for consultations (27.7% [28/101] vs. 14.9% [18/121], $p = 0.021$). Barriers identified included lack of knowledge among users, technical limitations, and data protection concerns. Physicians were more concerned about high costs (14.9% [15/101] vs. 4.1% [5/121] of patients, $p = 0.011$) and insufficient evidence of benefits (26.7% [27/101] vs. 9.1% [11/121], $p = 0.001$).

Table 3 Technology readiness among patients and physicians; presents the percentage of patients and physicians who agreed with each statement regarding their technology readiness. Percentages are based on the total number of respondents per group (Patients: $n = 121$, physicians: $n = 101$)

Question	Frequency (in %) Patients	Frequency (in %) Physicians	*p* value
Whether I am successful in using modern technology largely depends on me.	76 (62.8)	57 (56.4)	0.408
It is up to me whether I succeed in using technological innovations – it has little to do with luck.	79 (65.3)	63 (62.4)	0.757
I am very curious about technological innovations.	73 (60.3)	81 (80.2)	0.002
What happens when I engage with technological innovations is ultimately under my control.	64 (52.9)	61 (60.4)	0.324
I quickly develop a liking for technological innovations.	62 (51.2)	66 (65.3)	0.048
When I have difficulties with technology, it ultimately depends on me to solve them.	46 (38.0)	35 (34.7)	0.705
I am always interested in using the latest technological devices.	47 (38.8)	61 (60.4)	0.002
If I had the opportunity, I would use technological products even more frequently than I do currently.	33 (27.3)	56 (55.4)	0.000
Dealing with technological innovations is often overwhelming for me.	16 (13.2)	12 (11.9)	0.923
I often fear failing when dealing with modern technology.	14 (11.6)	11 (10.9)	1.000
I find it difficult to handle new technology – I usually just can't do it.	14 (11.6)	7 (6.9)	0.344
I am afraid of breaking technological innovations rather than using them correctly.	8 (6.6)	14 (13.9)	0.115

Table 4 Perceived Usefulness of Digital Health Services in Chronic Urticaria Management: Patient and Physician Responses

“Do you consider the use of digital health services (e.g., medical apps, video consultations) useful for managing urticaria?”			***p*-value**
Response	**Patients Frequency (%)**	**Physicians Frequency (%)**	**0.09124**
Applies	72 (59.5)	76 (75.3)	
Neutral	26 (21.5)	15 (14.9)	
Does not apply	10 (8.3)	4 (4.0)	
Missing	13 (10.7)	6 (5.9)	

Table 5 Frequency and percentage of patients agreeing with the use of digital health services for managing urticaria by demographic group

“Do you consider the use of digital health services (e.g., medical apps, video consultations) useful for managing urticaria?”	**Frequency (% of Patients in the category (agree/strongly agree))**
Age Group	$p = 0.617$
Under 30	18 (50.0)
30–39	28 (67.9)
40–49	12 (75.0)
50–59	25 (64.0)
60 and above	11 (72.7)
Gender	$p = 0.147$
Female	78 (61.5)
Male	22 (81.8)
Educational Status	$p = 0.554$
Still in school	5 (40.0)
Still in vocational training	5 (80.0)
No vocational qualification	2 (50.0)
Vocational training of at least one year	37 (73.0)
University degree	49 (63.3)
Place of Residence	$p = 0.187$
Rural area (community under 5,000 inhabitants)	21 (76.2)
Small town (5,000–20,000 inhabitants)	21 (81.0)
Medium-sized town (20,000–100,000 inhabitants)	19 (68.4)
Large city (over 100,000 inhabitants)	17 (47.1)
Metropolitan city (over 1,000,000 inhabitants)	22 (59.1)

Discussion

Key results

This study assessed the acceptance, utilization, and perceived barriers of digital health services among patients with CU and their healthcare providers in Germany. The findings revealed that a significant majority of physicians (75.3%) and a substantial proportion of patients (59.5%) consider digital health services useful for managing CU. Physicians demonstrated higher enthusiasm and readiness to adopt technological innovations compared to patients, with 80.2% expressing curiosity about new technologies versus 60.3% of patients. Although physician caseloads may influence responses, our stratified analysis showed no significant impact on digital health service acceptance. Despite the positive attitudes, notable barriers were identified, including concerns about data privacy, technical infrastructure limitations, and a lack of awareness of available digital services. The COVID-19 pandemic positively influenced attitudes toward digital health services, particularly among physicians, with 46.5% reporting a more favorable view due to the pandemic compared to 29.8% of patients. Despite expectations, educational background did not significantly impact the use of digital health services (Appendix 1).

Interpretation and comparison with literature

Our sample had a higher proportion of female participants, a trend seen in other studies on urticaria prevalence [3, 33, 34]. Nevertheless, our sensitivity analysis revealed no significant gender differences in the acceptance of digital health services.

The results indicate a growing recognition of the potential benefits of digital health services in CU management among both patients and physicians. The higher acceptance among physicians aligns with findings by Ruggiero et al., who reported increased enthusiasm for teledermatology among dermatologists, especially after the onset of the COVID-19 pandemic [35]. The pandemic has accelerated the adoption of digital health services. 46.5% of physicians in our study report a more positive attitude towards digital solutions due to COVID-19. This is consistent with the observations of Kruse, Monaghesh and Hajizadeh, who have seen a faster adoption of telemedicine across specialties [25, 36, 37].

Patients’ positive attitudes, though less pronounced than physicians’, are consistent with Cherrez-Ojeda et al., who found that patients with CU are increasingly open to digital tools for disease management [21]. Furthermore, a recent publication on the hybrid care potential of teledermatology in skin diseases demonstrated that linking digital and inperson care can enhance patient satisfaction and support disease management [25]. The critical evaluation of health information often requires specialist knowledge that is difficult for lay people to access. Our results show that only 30.6% of patients feel confident to make health-related decisions based on online information. This underlines the importance of trusted medical sources such as professional societies and specialized clinics to provide patients with reliable information. While in our study 22% stated that they felt unsure about

Table 6 Comparison of patients' and physicians' attitudes toward digital health services

	Patients Frequency (%) $n = 121$ (100)	Physicians Frequency (%) $n = 101$ (100)	*p*-value
Has your attitude towards digital health services changed due to COVID-19?			
Yes, it has become more positive	36 (29.75)	47 (46.5)	0.04891
No, it has not changed	65 (53.72)	42 (41.6)	
Yes, it has become more negative	6 (4.96)	6 (5.9)	
Missing	14 (11.57)	6 (5.9)	
Do you use more digital health services since COVID-19?" (Patients)/"Do you offer more digital health services since COVID-19? (Physicians)			
Yes	38 (31.4)	34 (33.7)	0.6072
No	70 (57.9)	60 (59.4)	
Missing	13 (10.7)	7 (6.9)	
How does digitalization in urticaria care affect the doctor-patient relationship?			
Very positive	14 (11.6)	8 (7.9)	0.1308
Rather positive	24 (19.8)	33 (32.7)	0.1337
Both positive and negative	25 (20.7)	32 (31.7)	0.261
Rather negative	12 (9.9)	9 (8.9)	0.5377
Very negative	2 (1.6)	2 (2.0)	1
Not at all	24 (19.8)	9 (8.9)	0.0005
Missing	20 (16.5)	8 (7.9)	0.002
How does digitalization in urticaria care affect the quality of care?			
Very positive	22 (18.2)	22 (21.8)	1
Rather positive	27 (22.3)	35 (34.7)	0.2085
Both positive and negative	25 (20.7)	19 (18.8)	0.2864
Rather negative	7 (5.8)	9 (8.9)	0.7244
Very negative	3 (2.5)	2 (2.0)	1
Not at all	16 (13.2)	6 (5.9)	0.006
Missing	21 (17.4)	8 (7.9)	0.0014
For which purpose/area would you use video consultations in the future?			
First appointment	22 (18.2)	12 (11.9)	0.0283
Follow-up appointment	44 (36.4)	52 (51.5)	0.3123
Not at all	19 (15.7)	21 (20.8)	0.8233
Emergency appointment	16 (13.2)	6 (5.9)	0.006
Other	5 (4.1)	4 (4.0)	1
Missing	15 (12.4)	6 (5.9)	0.0126
Would you be willing to forego an in-person appointment if your condition is stable and you could indicate that you are doing well using digital health services? If so, how?			
No, I prefer an in-person appointment, even if I am well and there is nothing to discuss	83 (68.6)	-	
Yes, digitally, preferably via phone call or video consultation (synchronous)	25 (20.7)	-	
Yes, digitally, preferably via digital questionnaire or email (asynchronous)	13 (10.7)	-	

making decisions based on online health information, in another study in the German general population [38] it is 32% and in a survey of people with rheumatic diseases 42.5% [39]. Our findings echoes Diviani et al., who highlighted that low health literacy impedes the ability to critically evaluate online health information [40]. Enhancing digital health literacy is crucial for empowering patients and facilitating the effective use of digital tools.

The identified barriers, such as data privacy concerns and technical infrastructure limitations, are consistent with those reported by Kruse et al. [41] in their systematic review of telemedicine adoption barriers. Our findings suggest higher acceptance of digital health services in small towns and rural areas, likely due to limited specialist access. Studies highlight teledermatology's benefits in such regions, improving expert access for CU patients [42, 43]. Another study [26] further confirms strong patient interest, reinforcing its role in bridging healthcare gaps.

Physicians in our study were more likely to perceive high costs (14.9% vs. 4.1% of patients, $p = 0.011$) and insufficient evidence of benefits (26.7% vs. 9.1% of patients, $p = 0.001$) as significant obstacles. This aligns with concerns about the financial and evidential aspects of digital health implementation discussed by Ross et al. [44], emphasizing the need for robust clinical

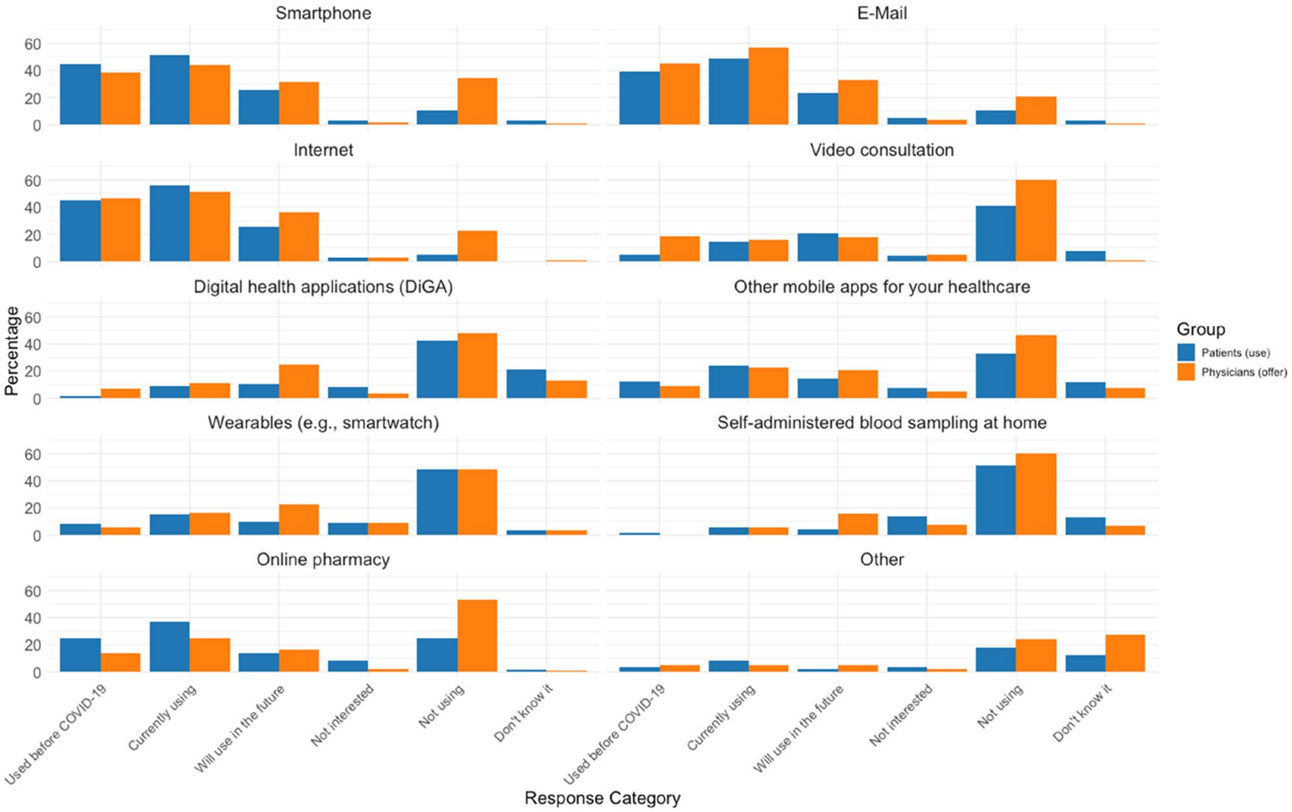

Fig. 2 Advantages and barriers of digital health services

evidence and cost-effectiveness analyses to support digital interventions.

The preference for in-person visits among patients, even when their condition is stable (68.6% preferred to continue in-person visits), reflects a desire for personal interaction and trust in traditional consultations. Additionally, first appointments in CU often require in-office challenge tests and hands-on examination - essential for confirming diagnosis and guiding treatment - that cannot be performed remotely, thereby limiting digital services primarily to follow-up care [45]. This is consistent with Moulaei et al. [46], who noted that despite the convenience of telemedicine, patients value the quality of care and personal connection inherent in face-to-face consultations.

However, mobile health (mHealth) tools are emerging as valuable solutions. The CRUSE® study demonstrated their feasibility [18, 19], with Sousa-Pinto et al. [20]. confirming their reliability. Cherrez-Ojeda et al. [47]. found strong patient interest, particularly among younger individuals, while Sørensen et al. [48] showed that smartphone photographs can support remote assessment [20].

Implications for practice

The higher enthusiasm among physicians suggests that they could play a pivotal role in promoting the adoption of digital health services. Their professional exposure to technological advancements and the necessity to adapt clinical practices during the pandemic position them as key facilitators in integrating digital tools into CU management. Engaging patients through education and addressing their concerns could bridge the gap between perceived usefulness and actual usage. Tailored interventions to improve digital health literacy, as recommended by Norman and Skinner [49], could enhance patients' confidence in using online health information.

Addressing data privacy concerns is essential. Implementing robust data protection measures and clearly communicating these to patients can alleviate fears related to privacy and security [41]. Improving technical infrastructure, such as ensuring reliable internet access and providing updated equipment, is necessary to support the effective delivery of digital health services [50].

Providing evidence of the efficacy and cost-effectiveness of digital health interventions is crucial to encourage adoption among healthcare providers [51]. Physicians' concerns about costs and insufficient evidence highlight the need for comprehensive studies demonstrating the clinical benefits and economic viability of digital health services [52, 53]. The ideal digital health intervention for improving the management of CU could involve a hybrid care model that combines mobile health apps, teledermatology, and remote monitoring through wearables or patient-reported outcomes. This integrated approach would allow for real-time symptom tracking, personalized care plans, and timely adjustments to treatment.

Limitations and generalisability

This study has several limitations. First, its cross-sectional design captures attitudes at a single time point, limiting our ability to infer causality or track changes over time; longitudinal studies are needed. Second, reliance on self-reported data may introduce response and social desirability biases, potentially overestimating positive attitudes. Third, selection bias is possible since those with an interest in digital health may have been more likely to participate, affecting the representativeness of our sample. Additionally, being conducted within the German healthcare system, cultural and technological differences may limit the applicability of our findings to other settings. Finally, we did not collect detailed clinical data on CU subtype or severity. Acceptance of digital health services might differ between chronic spontaneous and inducible urticaria (with varying anaphylaxis risks or symptom control), so future studies should stratify participants by CU subtype and UCT score to guide tailored digital care solutions. While our study provides valuable insights into digital health service perceptions in CU management in Germany, caution is needed when generalizing to other settings, as differences in healthcare infrastructure, cultural attitudes, and digital literacy could significantly influence adoption rates. Further research in diverse contexts is essential to validate and extend these findings [54, 55].

Conclusion

This study extends the previous study on teledermatology [26] by evaluating digital health literacy, technology readiness, and the acceptance and perceived barriers of digital health services among patients with chronic urticaria (CU) and their healthcare providers. Our findings indicate a generally positive attitude toward digital health tools, with physicians showing greater enthusiasm compared to patients. However, despite the potential of digital platforms to complement conventional care, in-person visits remain crucial—especially for first appointments where handson assessments (e.g., challenge tests) are necessary to confirm diagnosis and guide treatment. Smartphones, the Internet, and email are widely used in CU management, while video consultations and DiGA remain underutilized. Digital tools mainly support communication, symptom monitoring, and prescriptions, but broader integration is needed.

The insights gained here not only refine our digital care model for CU management but also underscore the need for further robust clinical evidence and cost-effectiveness analyses. Future studies should incorporate longitudinal designs, detailed clinical stratification (e.g., CU subtype and UCT scores), and comparisons across diverse healthcare settings to optimize and tailor digital care solutions.

Overall, our study reinforces the potential of digital interventions to enhance chronic urticaria management while highlighting areas for improvement in technology integration and clinical validation.

Appendix

Sensitivity analysis for'Agree/Strongly Agree (including Neutral)

Question	Frequency (%) Patients
"Do you consider the use of digital health services (e.g., medical apps, video consultations) useful for managing urticaria?"	Agree/ Strongly Agree (including Neutral)
Gender	
Divers	1 (0.8)
Male	20 (16.5)
Female	71 (58.7)
Age	
< 30	15 (12.4)
30–49	38 (31.4)
50+	33 (27.3)
Residence	
Small Town	19 (15.7)
Rural Region	20 (16.5)
Medium City	19 (15.7)
Large City	14 (11.6)
Million City	20 (16.5)
Highest Educational Status	
No vocational qualification	1 (0.8)
Currently a student	4 (3.3)
Currently in vocational training	5 (4.1)
Completion of at least one year of vocational training	35 (28.9)
University degree	45 (37.2)
Missing	8 (6.6)

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Authors' contributions

M.H. conceptualized and designed the analysis, collected the data, performed the analysis, and was the primary author of the article.T.B. critically reviewed and provided feedback on the paper.A.Z. critically reviewed and provided feedback on the paper.J.K. critically reviewed and provided feedback on the paper.R.D. critically reviewed and provided feedback on the paper.M.W. critically reviewed and provided feedback on the paper.S.M. conceptualized and designed the analysis, critically reviewed, and provided feedback on the paper.F.M. conceptualized and designed the analysis, critically reviewed, and provided feedback on the paper.

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Data availability
All data generated or analyzed during this study are included in this published article. All aggregate data collected for this article are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All participants provided written informed consent. The study was reviewed and approved by the Ethics Committee of the Brandenburg Medical School (MHB) (reference: E-02-20220224) and the Ethics Committee of the Technical University of Munich (reference: 2022-390-S-SR).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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ORIGINAL ARTICLE

Bridging the gap through telemedicine: Pilot study on the acceptance and use of teledermatology for urticaria

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Summary
Background: Chronic spontaneous urticaria (CSU) significantly impairs patients' quality of life. Despite advances in diagnosis and therapy, treatment is still unsatisfactory. Telemedicine offers a promising solution to improve treatment. This pilot study assesses the acceptability and utilization of a digital health model for CSU, examines its impact on disease management, and identifies technical challenges.
Patients and Methods: In this prospective pilot study, CSU patients at a university hospital in Germany were included. Over 12 months, participants interacted with physicians via a telemedicine platform, which was the study-specific intervention. After each three-month digital visit, symptoms and quality of life were assessed using electronic patient reported outcomes (ePROs) and online questionnaires. In the end, patients and doctors rated the overall satisfaction, the user-friendliness of the platform and the technical challenges.
Results: 24 patients completed the study. The majority (92%) reported that the digital concept could be a promising alternative to traditional consultations. Analysis from baseline to end of study revealed that disease control remained stable while quality of life improved. All physicians found the digital application reliable and time-saving.
Conclusions: This pilot study demonstrates the feasibility and high acceptance of a digital health model for the management of CSU. Further research with larger cohorts is needed and planned to determine broader applicability.

KEYWORDS
Chronic Urticaria, teledermatology, telemedicine, urticaria control test

INTRODUCTION

Chronic spontaneous urticaria (CSU) is a common dermatological condition affecting approximately 1% of the population.[1–3] It is characterized by recurrent itchy hives and, in some instances, angioedema, which significantly diminishes the quality of life and leads to substantial psychosocial stress for those affected.[4–14]

Despite advances in diagnosis and therapy, including biologics and modern antihistamines, the treatment of many patients with chronic urticaria remains unsatisfactory.[8,15,16] This gap is further exacerbated by the transient and intense nature of CSU flare-ups, which often subside before professional medical intervention, leaving healthcare providers unaware of the full extent of the patients' suffering.[5,6,9] Digital healthcare technologies present a promising solution to bridge this gap in CSU management. Incorporating Store-and-Forward technologies and real-time online interactions like chat-based consultations and video conferencing offers significant potential to enhance early and ongoing patient engagement.[17,18] These digital interventions facilitate seamless communication and efficient appointment scheduling and will prove useful in case of an emerging need for infection control measures.[18,19]

In the evolving digital health landscape, there is a growing acceptance among patients, particularly for chronic conditions like CSU. This condition predominantly affects individuals between 40 and 59 years of age and usually does not necessitate extensive laboratory and other investigations in routine care, making it an ideal candidate for digital health interventions.[7,20,21]

This demographic and clinical profile makes CSU a suitable model for exploring the effectiveness and adaptability of digital healthcare systems. Despite this potential, a tailored digital care model designed specifically for CSU patients has not yet been fully realized. Our pilot study, therefore, aimed to provide a framework for such a model.

The aim of the pilot study was firstly to determine the acceptance and utilization of a digital care structure by CSU patients. Secondly, we wanted to determine the acceptance of this approach by physicians, identify technical barriers to implementation in everyday clinical practice and propose practical solutions to overcome the challenges. Through this research, we aimed to provide valuable insights and practical solutions that can optimize the management of CSU using digital health technology and enable continuous monitoring.

PATIENTS AND METHODS

Study design and setting

The study was designed as a prospective, monocentric observational pilot study with a 12-month follow-up period. It was conducted from March 2022 to December 2023 at the Department of Dermatology and Allergology, Klinikum rechts der Isar, Technical University of Munich. It was approved by the Ethics Committee of the Technical University of Munich (reference number 2022-217-S-NP).

Participants

Patients with confirmed diagnoses of CSU and controlled disease states, as indicated by an Urticaria Control Test (UCT) score greater than or equal to 12 were included.[22] Recruitment primarily occurred through the clinic, ensuring targeted selection aligned with the study's objectives. The patient cohort included individuals undergoing various medication-based treatments, categorized into groups based on simple antihistamine use, multiple antihistamine use (2 or more pills per day), or other therapies such as biologics or modern treatments. Exclusion criteria included acute urticaria, concurrent dermatological conditions impacting diagnosis or treatment, and uncontrolled CSU (UCT score < 12). Additionally, participants must have received medication-based treatment and be willing to utilize a study-specific digital application for further monitoring.

Video consultation platform

A digital platform (medflex) was used for real-time video consultations, photo transfers, and chat messages. The platform is a certified video service solution for the medical sector in Germany that serves as a tool for video consultations between physicians and patients. The platform offers individual and group video consultations. It enables the secure transmission of messages, photos, and documents to physicians.

Follow-up

Participants were followed for 12 months, during which they received scheduled and guideline-compliant dermatological treatment. Digital physician-patient interactions were scheduled every 3 months following guidelines.[3] In addition, appointments were arranged as required in the event of complaints or exacerbations through proactive patient enquiries. Throughout the study period, participants had the opportunity to digitally document their care via the online platform via chat or photo. If a patient needed an appointment on-site due to an exacerbation or a prescription, this was arranged directly in the allergy department.

Questionnaires and variables

The questionnaire and patient reported outcomes (ePROs) were collected digitally through an online platform (RedCap, Vanderbilt University). ePROs involve direct input from patients regarding their symptoms, quality of life, and overall health, allowing for a more accurate and real-time assessment of chronic conditions like CSU. The online questionnaire was conducted by a multidisciplinary team using standardized and validated questionnaires (UCT, DLQI) and questions based on a previous study.[23] The UCT is a specific measurement tool for assessing the control of urticaria symptoms, with scores ranging from 0 to 16, with higher scores indicating better control.[22] A score lower than 12 indicates non-controlled urticaria. The DLQI quantifies the impairment of quality of life caused on a scale of 0 to 30, with higher scores representing greater impairment.[24] The Happiness Score measures general well-being with the question "Taking all things together, how happy would you say you are?" on a scale from 0 (extremely unhappy) to 10 (extremely happy).[25]

Following each online visit every 3 months, patients were sent online questionnaires. The patient questionnaires focused on demographic data and patient-reported outcomes (PROs), such as disease control with UCT, DLQI, and

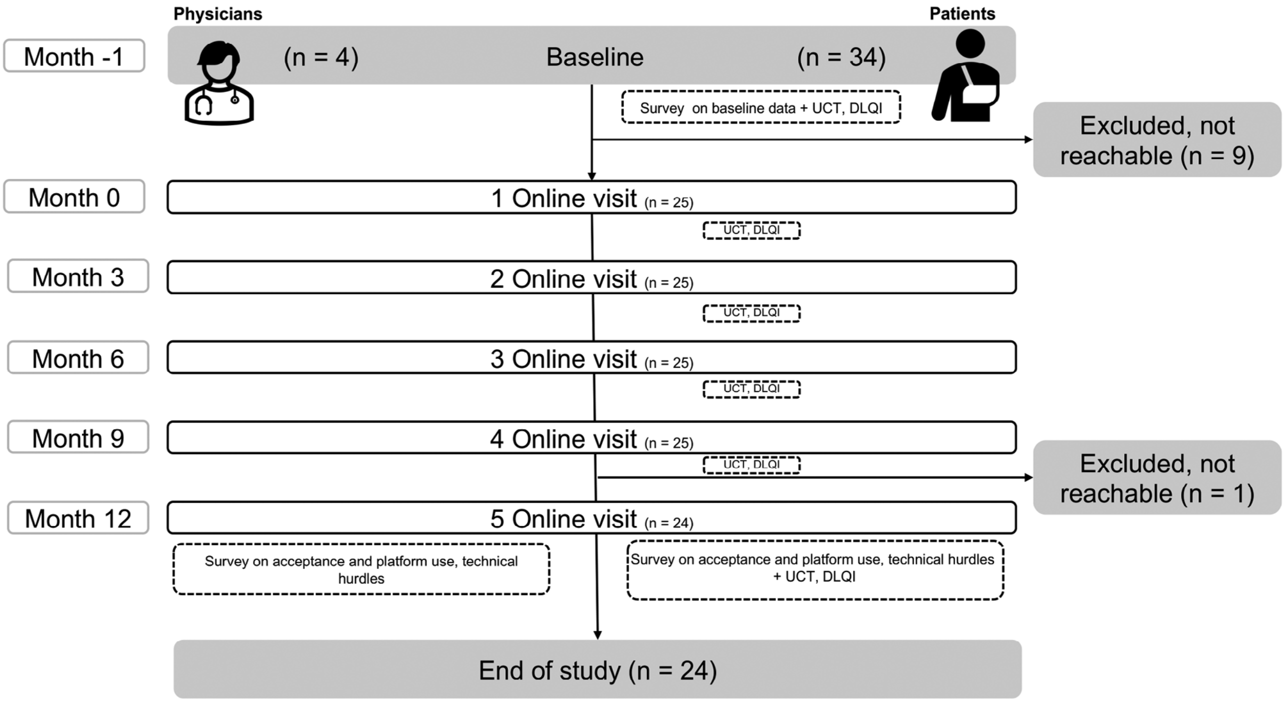

FIGURE 1 Study flow chart and time points of questionnaires: Flowchart showing the enrollment of 34 patients, with 25 registering on the platform. Questionnaires assessing disease control (UCT) and quality of life (DLQI) were administered after each visit and at the end of the study for overall satisfaction. Abbr.: UCT, Urticaria Control Test; DLQI, Dermatology Life Quality Index; n, number

the overall Happiness Score.[26] At the end of the study, a questionnaire on overall satisfaction and acceptance based on a previous study of the digital care approach was sent.[23] In addition, each physician who carried out the video consultations received a questionnaire on their experiences with the digital platform (functionality, user-friendliness). This also covered the integration of the application into everyday clinical practice and any technical challenges.

For demographic analysis, participants were stratified into age categories (18–24, 25–34, 35–44, 45–54, and 55+). Participants' residential areas were categorized into four distinct groups based on population size. These categories encompassed large cities (with more than 100,000 inhabitants), medium-sized towns (with 20,000 to 99,999 inhabitants), small towns (with 5,000 to 19,999 inhabitants), and rural communities (with fewer than 5,000 inhabitants).

Study size

The study was designed as a pilot study with at least 20 participants recruited. This sample size was deemed sufficient for the exploratory nature of the research, allowing for preliminary insights into the acceptance and utilization of digital healthcare concepts among CSU patients.[27,28] Recognizing the potential dropout rate associated with pilot studies, which we estimated to be approximately 30%, we proactively recruited a larger initial sample to mitigate potential data loss.[29]

Statistical methods

Data management and statistical analyses were performed using R version 4.2.1 and IBM SPSS Statistics 28 (IBM Corporation, Armonk, NY, USA).[30,31] Descriptive statistics were performed to describe patient demographics, clinical characteristics, and physician and patient acceptance. Normal distribution was assessed using the Shapiro-Wilk test. For non-normally distributed data, appropriate non-parametric tests, such as the Wilcoxon signed-rank test, were used to analyze UCT, DLQI and Happiness scores. Comparisons were made between scores at baseline (month -1 (month of recruiting)) and month 12 to evaluate changes in symptom control, quality of life, and patient happiness over the study period.

RESULTS

Participants

Between May and December 2022, 34 patients with CSU were asked to participate in our pilot study. After comprehensive information about the study, informed consent was obtained. 25 patients successfully registered on the digital platform (Figure 1). The remaining nine patients either could not be reached ($n = 6$) or expressed no further interest in participating during the first contact attempts ($n = 3$). A further drop-out occurred due to unavailability after the

TABLE 1 Patient baseline questionnaire.

Question	Answer	Frequency (in %)
Age category	18–24	4 (16.7)
	25–34	6 (25.0)
	35–44	8 (33.3)
	45–54	5 (20.8)
	55+	1 (4.2)
Gender	Female	15 (62.5)
	Male	9 (37.5)
Highest educational qualification	Up to intermediate school certificate	6 (25.0)
	Advanced technical college entrance qualification	5 (20.8)
	A-Levels	4 (16.7)
	University of Applied Sciences	2 (8.3)
	University	7 (29.2)
You live in a …	Large city (more than 100,000 inhabitants)	10 (41.7)
	Medium-sized city (between 20,000 and 99,999 inhabitants)	3 (12.5)
	Small town (between 5,000 and 19,999 inhabitants)	7 (29.2)
	Rural municipality (less than 5,000 inhabitants)	4 (16.7)
How many years have you had urticaria?	< 2 years	9 (37.5)
	2–4 years	11 (45.8)
	More than 4 years	4 (16.7)
Who knows about your illness? (multiple answers possible)	Spouse	9 (37.5)
	Life partner	8 (33.3)
	Family members	22 (91.7)
	Friends	21 (87.5)
	Employer	10 (41.7)
	Other	2 (8.3)
What medication are you currently taking for your urticaria? (multiple answers possible)	Antihistamine intake (1 times daily)	6 (25.0)
	Antihistamine intake (2–4 times daily)	10 (41.7)
	I also take a biologic (injection) or another modern form of therapy	15 (62.5)
How many different GP practices have you been to for your urticaria?	0	6 (25.0)
	1	7 (29.2)
	2	6 (25.0)
	3	1 (4.2)
	4	1 (4.2)
	5	1 (4.2)
	> 5	2 (8.3)
How many different dermatological practices have you been to for your urticaria?	0	3 (12.5)
	1	6 (25.0)
	2	8 (33.3)
	≥ 3	6 (25.0)
	Missing	1 (4.2)
How many other physicians have you seen for your urticaria?	0	8 (33.3)
	1–2	5 (20.8)
	> 3	11 (45.8)
	Missing	2 (8.3)
How many physicians are you currently seeing for your urticaria?	1	18 (75.0)
	2	3 (12.5)
	> 3	3 (12.5)
How far is your journey to the clinic?	< 5 km	4 (16.7)
	≥ 5 to < 10 km	5 (20.8)
	≥ 10 to < 25 km	7 (29.2)
	≥ 25 km	8 (33.3)
How did you travel here?	Car	12 (50.0)
	Public transport	9 (37.5)
	Bicycle	2 (8.3)
	Scooter/Motorbike	1 (4.2)
How much time do you need on average for the journey?	< 30 min	8 (33.3)
	≥ 30 to < 60 min	11 (45.8)
	≥ 60 min	5 (20.8)
How long was the average waiting time at the clinic (routine appointments)?	< 30 min	4 (16.7)
	≥ 30 to < 60 min	17 (70.8)
	≥ 60 min	3 (12.5)
How long was the average waiting time at the clinic for a previous acute presentation (without a previously scheduled appointment)?	< 15 min	1 (4.2)
	≥ 15 to < 30 min	2 (8.3)
	≥ 30 to < 60 min	2 (8.3)
	≥ 60 min	10 (41.7)
	I had no previous acute presentation	9 (37.5)
How much would you be willing to pay for a digital physician contact? (Duration 15 min)	< 20 €	11 (45.8)
	≥ 20 € to < 50 €	11 (45.8)
	Missing	2 (8.3)
How much would you be willing to pay for a personal consultation? (Duration 15 min)	< 20 €	10 (41.7)
	≥ 20 € to < 50 €	9 (37.5)
	≥ 50 € to < 100 €	2 (8.3)
	Missing	3 (12.5)
How often have you used digital health applications in the last 3 months?	Not at all	21 (87.5)
	Less than 1 time per month	1 (4.2)
	At least once a month	2 (8.3)

(Continues)

TABLE 1 (Continued)

Question	Answer	Frequency (in %)
How good are you at using digital applications?	Outstanding	10 (41.7)
	Very good	8 (33.3)
	Quite good	4 (16.7)
	Not particularly good	2 (8.3)
Have you ever used a video consultation with a physician before?	Yes	5 (20.8)
	No	19 (79.2)
If so, which application?	Nutritional counselling, psychologist, psychotherapy, Zoom	4 (80)
	Missing	1 (20)
How often have you used them?	Four times	3 (12.5)
	More than four times	2 (8.3)

penultimate online visit. During the study, three patients required extra unscheduled visits due to exacerbations and additional consultation regarding their treatment.

In the study of 24 participants, 62.5% were female and 37.5% male, represented by a wide age range from 18 to over 55 (Table 1). The majority (54.2%) lived in urban areas, while 45.8% were from smaller towns or rural areas. Urticaria had been known for between 2–4 years in 45.8% of participants. In 41.7% of cases, antihistamines were taken regularly. Over 62.5% were treated with biologics or other modern therapies.

More than half of the participants (54.2%) had visited more than one general practice and 58.3% had visited more than one dermatological practice before the study. The distances to the clinic varied, with 33.3% travelling more than 25 kilometers. Half of the patients (50%) travelled by car to the clinic and the average journey time was more than 30 minutes for 83.3% of patients. Waiting times for routine visits were longer than 30 minutes for 83.3% of patients, while waiting times for emergency visits were longer than 60 minutes for 41.7% of patients. A large proportion (87.5%) had not used any digital health applications in the last 3 months. Only 20.8% had experience with video consultations.

Patients' perceptions and acceptance of the digital care concept

Regarding patient perceptions of the CSU digital care concept, the analysis revealed a high level of acceptance and satisfaction (Figure 2, Table 2). The majority (92%) agreed that the digital application is a good alternative to face-to-face consultations and that it is possible to discuss health-related problems within the platform (100%). Regarding avoiding in-person physician visits through the digital application, agreement was slightly lower, with 79% stating that the application enabled them to avoid in-person

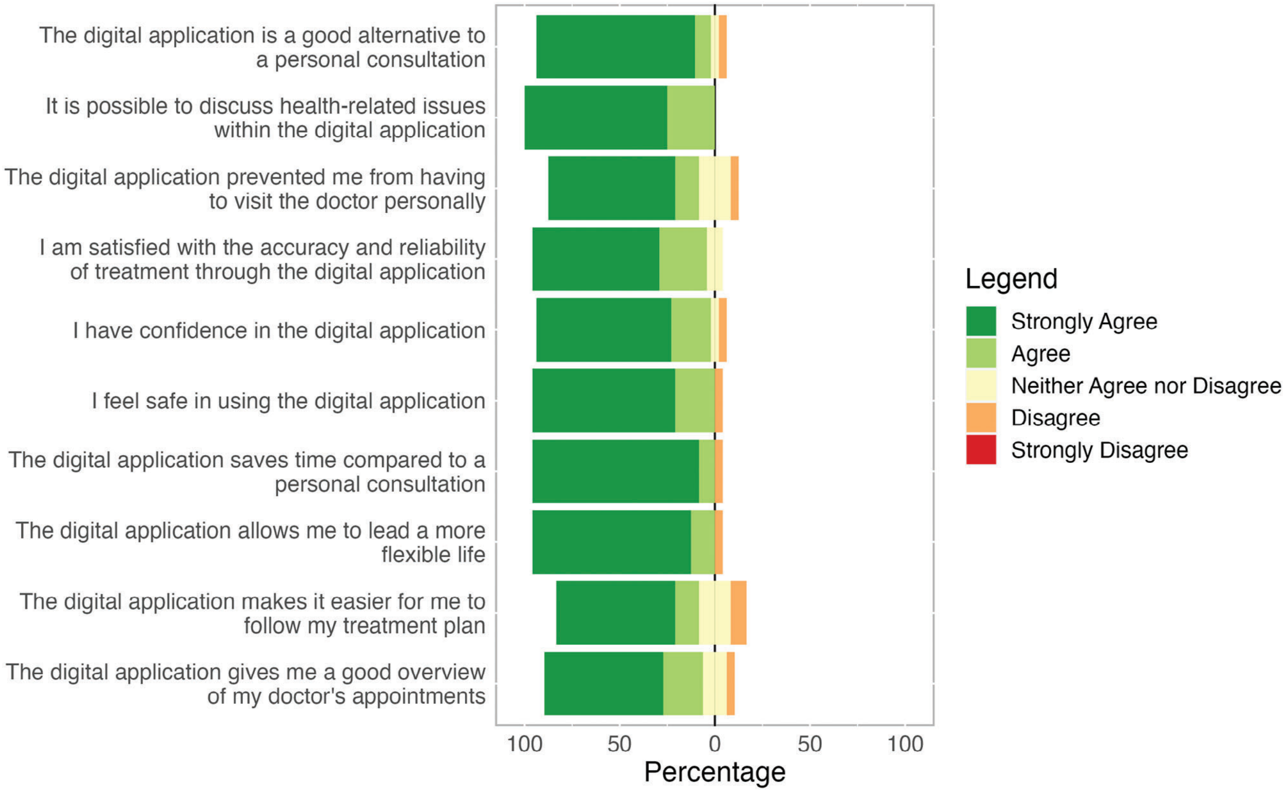

FIGURE 2 Patient perceptions and acceptance of the digital care concept: Summary of patients' perception of the digital application and highlights its effectiveness as an alternative to face-to-face consultations, its trustworthiness, and its benefits for disease management.

TABLE 2 Patient questionnaire (end of study, month 12).

Question	Answer	Frequency (in %)
How many contacts have you had with the physician via the digital application in the last 3 months?	0	2 (8.3)
	1	10 (41.7)
	2	9 (37.5)
	3	2 (8.3)
	5	1 (4.2)
How long was the average waiting time for a new appointment?	< 7 days	9 (37.5)
	≥ 7 to < 10 days	1 (4.2)
	≥ 1 month to < 3 months	4 (16.7)
	No appointment made	10 (41.7)
How satisfied were you with your last online appointment with the physician?	Very satisfied	18 (75.0)
	Quite satisfied	4 (16.7)
	Neither	1 (4.2)
	Missing	1 (4.2)
What did you like best about using the digital application?	More flexibility	2 (8.3)
	Time saving	21 (87.5)
	Other	1 (4.2)
Have you ever been in contact with another physician through a video application?	Yes	5 (20.8)
	No	19 (79.2)
If so, how often?	More than 2 times	5 (8.8%)
What other digital applications do you use? (multiple answers)	App for video telephony (e.g. WhatsApp, Skype, Zoom)	19 (33.3)
	App for social media (e.g. Instagram, Facebook, TikTok…)	18 (31.6)
	App for nutrition tracking	6 (10.5)
	App for period tracking	6 (10.5)
	Other	5 (8.8)
	None	2 (3.5)
	App for sleep tracking	1 (1.8)
Has the coronavirus pandemic led to more frequent use of the digital applications mentioned above?	Yes	16 (66.7)
	No	8 (33.3)
How often have you used digital applications in the last 3 months?	Daily	19 (79.2)
	Several times a week	1 (4.2)
	Once a week	1 (4.2)
	Once a month	1 (4.2)
	Never	2 (8.3)
How often have the following problems occurred when using the digital application in the last 3 months?	Limitations in the text display	21 (16.0)
	Limitations on registration	20 (15.3)
	Limitations when starting the application	19 (14.5)
	Limitations in handling	19 (14.5)
	Limitations on data transmission	18 (13.7)
	Limitations in sound quality	17 (13.0)
	Limitations in image quality	17 (13.0)
	Limitations in the text display	21 (16.0)
What is your overall assessment of the severity of the technical problems?	No problems encountered	18 (75.0)
	Very light	3 (12.5)
	Quite light	2 (8.3)
	Quite heavy	1 (4.2)

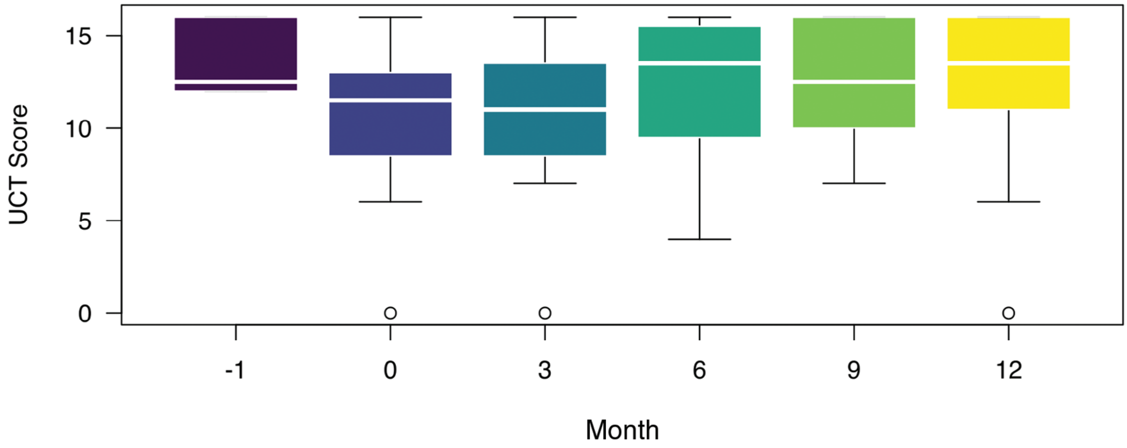

FIGURE 3 UCT score over time: Boxplots of UCT scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction indicated a decrease in UCT scores from a mean of 13.67 at month -1 to 12.58 at month 12 (V = 77, p = 0.35), suggesting no significant change in symptom control over the study period.

physician visits. Nevertheless, patients confirmed a high level of satisfaction with the accuracy and reliability of treatment (92%) as well as a strong sense of trust (92%) and safety (96%) when using the digital application. Furthermore, 96% of patients reported that the application saves time compared to face-to-face consultations and allows them to organize their lives more flexibly. Even though the approval rates for making it easier to track treatment plans (75%) and keep track of physician's appointments (83%) are slightly lower, the overall results show a high level of acceptance.

Disease control, quality of life, and happiness during the pilot study period

Figure 3 illustrates boxplots for UCT scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction indicated a decrease in scores from a mean of 13.67 at month -1 to 12.58 at month 12 (V = 77, p = 0.35). Figure 4 shows boxplots for DLQI scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction indicated a decrease in scores from a mean of 7.25 at month -1 to 3.54 at month 12 (V = 108.5, p = 0.04). Figure 5 displays boxplots for Happiness Scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction showed no significant difference in scores, with means of 6.42 at month -1 and 6.67 at month 12 (V = 94.5, p = 0.71).

Technical assessment

An important aspect of our pilot study was the comprehensive assessment of potential technical barriers encountered by participants throughout the study period. After the final visit, all participants were surveyed regarding sound,

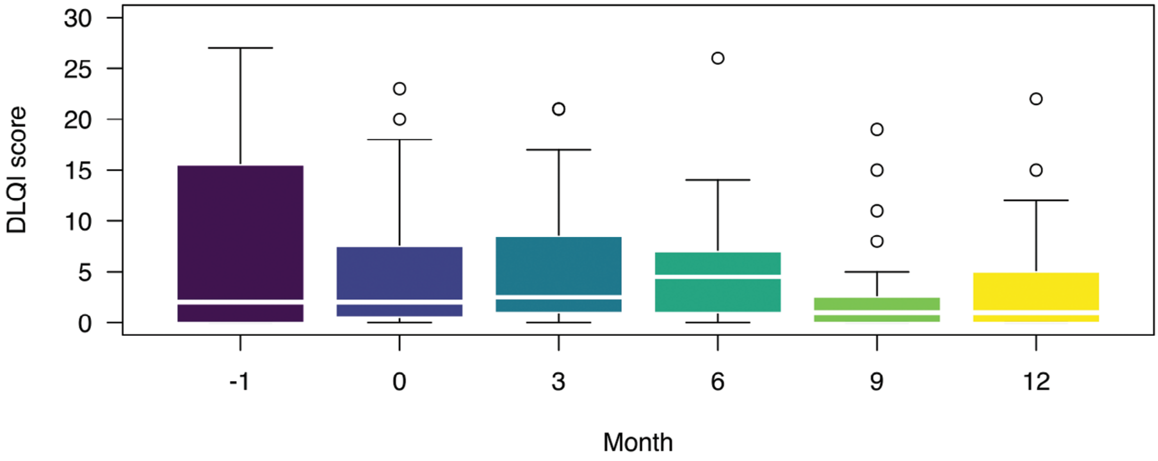

FIGURE 4 DLQI score over time: Boxplots of DLQI scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction indicated a decrease in DLQI scores from a mean of 7.25 at month -1 to 3.54 at month 12 (V = 108.5, p = 0.04), suggesting an improvement in the quality of life over the study period.

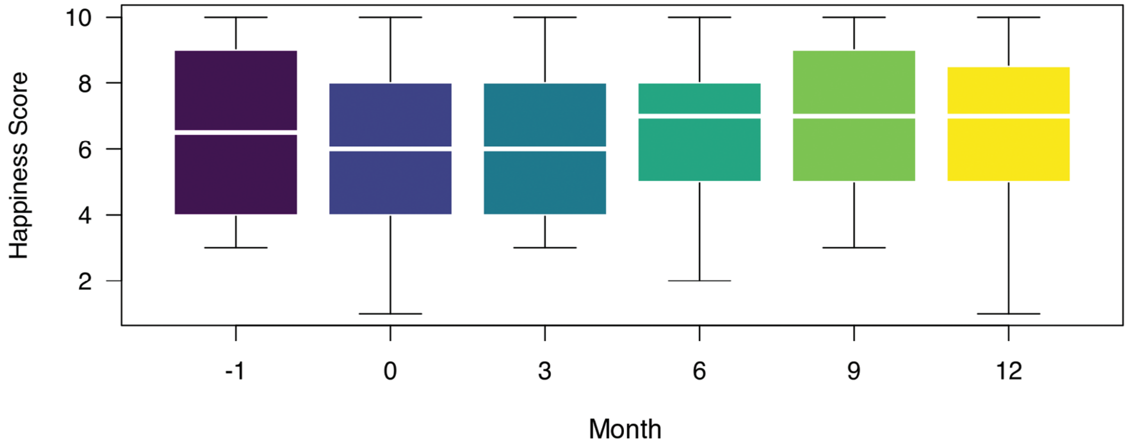

FIGURE 5 Happiness score over time: Boxplots of Happiness Scores at each visit. The Wilcoxon Signed-Rank Test with continuity correction showed no significant difference in Happiness Scores, with means of 6.42 at month -1 and 6.67 at month 12 ($V = 94.5$, $p = 0.71$), suggesting no significant change in patients' happiness over the study period.

video, text, data transfer, ease of use, login procedures, and application launch. In general, most participants reported minimal or no problems in these areas. However, it is worth noting that two participants repeatedly encountered difficulties, particularly in relation to ease of use and logging into the application. On closer inspection, these issues were found to be related to setting up the account and receiving the invitation emails. Online questionnaires and registration invitation emails were often incorrectly classified as spam, leading to delays in delivery to recipients. As a result, additional measures had to be taken in some cases to ensure successful patient registration. For example, setting up the application on site with the patient or pointing out the need to check the spam folder could help.

Physician questionnaire results and acceptance of digital application

Four physicians participated in the pilot study, all of whom reported positive views on the digital application for patient monitoring (Table 3). All participating physicians agreed that the application was a reliable instrument for patient monitoring. They agreed that this application is reliable and that the quality of image transmissions is sufficient. Physicians perceived the digital application as time-saving compared to face-to-face consultations and stated that data collection via the application reduced consultation time. Most physicians believed that the application could be used without training. All four physicians considered the digital application a viable alternative to face-to-face consultations. Two physicians already had experience with digital applications in telemedicine. The assessment of the technical problems revealed that one physician regarded them as very minor and another as rather minor. The remaining two physicians stated that they had no problems. One physician faced registration issues due to an unclear account assignment on the platform.

DISCUSSION

To our knowledge, this 12-month pilot study is the first to evaluate a digital telemedicine care model specifically for patients with CSU, focusing on the specific needs of this under-treated group. The study emphasizes the acceptance of a digital care structure for telemedical care and provides important insights into patient and physician acceptance, quality of life, and patient satisfaction. The high acceptance of telemedicine among CSU patients and treating physicians shows that digital care could complement or even be an alternative to traditional face-to-face consultations for well-controlled CSU. It enabled continuous management of CSU with timely intervention for exacerbations and maintained patient engagement through easily accessible, flexible communication options. The results showed that this approach can potentially provide long-term management for controlled CSU.

Study participants' responses to various user experience criteria – ease of use, trust, and time efficiency – emphasize the potential of telemedicine to improve adherence and overall satisfaction. The flexible delivery of visits plays a key role in maintaining disease control in CSU, which requires continuous monitoring. These important findings not only confirm the acceptability of the digital care model for CSU but also emphasize its potential for widespread adoption.

Strength and limitations

A key strength of this pilot study was its innovative approach specifically tailored to the management of CSU, a condition that requires regular monitoring and timely medical intervention. The digital concept proved effective by incorporating continous ePROs and enabling direct physician contact. Both patients and physicians reported a high level of acceptance and minimal technical problems. This suggest that digital health care models can

TABLE 3 Results of physician questionnaire.

Question	Answer	Frequency (in %)
How old are you?		Mean 31.00 (SD 4.8)
How much time do you allow for the initial presentation of acute urticaria?		10.00 (5.00)
How much time do you plan for the initial interview at CSU?		15.00 (4.08)
How much time do you allow for the routine check-up for urticaria?		7.50 (2.89)
How many urticaria patients (in total) do you treat per quarter?		100.00 (50.00)
How many chronic spontaneous urticaria patients do you treat per quarter?		50.00 (32.15)
Gender	Female	1 (25.0)
	Male	3 (75.00)
Which form of therapy do you mainly use for urticaria?	Antihistamines	2 (50.0)
	Biologics	1 (25.0)
	Systemic corticosteroids	0 (0.0)
	Topical therapy	0 (0.0)
	Other	1 (25.0)
Which form of therapy do you mainly use for psoriasis?	Antihistamines	0 (0.0)
	Biologics and small molecules	2 (50.0)
	Systemic corticosteroids	0 (0.0)
	Topical therapy	2 (50.0)
	Other	0 (0.0)
Which form of therapy do you mainly use for atopic eczema?	Topical therapy	2 (50.0)
	Light therapy	0 (0.0)
	Conventional system therapy	1 (25.0)
	Biologics	1 (25.0)
	JAK inhibitors	0 (0.0)
	Other	0 (0.0)
Which form of therapy do you mainly use for acne inversa?	Topical therapy	0 (0.0)
	Systemic antibiotic therapy	2 (50.0)
	Biologics	0 (0.0)
	Excision	1 (25.0)
	Missing	1 (25.0)
The digital application is a reliable tool for patient monitoring	Strongly agree	2 (50.0)
	Agree	2 (50.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)
Image quality is suitable for patient monitoring	Strongly agree	1 (25.0)
	Agree	2 (50.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	1 (25.0)
Patients adhere to the scheduled visits	Strongly agree	3 (75.0)
	Agree	1 (25.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)

(Continues)

TABLE 3 (Continued)

Question	Answer	Frequency (in %)
The digital application saves time compared to a personal consultation.	Strongly agree	3 (75.0)
	Agree	1 (25.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)
Data collection using the digital application reduces the counselling time	Strongly agree	3 (75.0)
	Agree	1 (25.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)
The digital application can be used without training	Strongly agree	2 (50.0)
	Agree	1 (25.0)
	Neither agree nor disagree	1 (25.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)
The digital application is a suitable alternative to face-to-face consultations	Strongly agree	2 (50.0)
	Agree	2 (50.0)
	Neither agree nor disagree	0 (0.0)
	Disagree	0 (0.0)
	Strongly disagree	0 (0.0)
Have you had any previous experience with digital applications in telemedicine?	Yes	2 (50)
	No	2 (50)
How good are you at using digital applications?	Excellent	2 (50.0)
	Very good	2 (50.0)
	Fairly good	0 (0.0)
	Not very good	0 (0.0)
	Not good at all	0 (0.0)
Limitations in sound quality	None	3 (75.0)
	Rare	1 (25.0)
	Now and then	0 (0.0)
	Constantly	0 (0.0)
Limitations in image quality	None	3 (75.0)
	Rare	1 (25.0)
	Now and then	0 (0.0)
	Constantly	0 (0.0)
Limitations in handling	None	2 (50.0)
	Rare	1 (25.0)
	Now and then	1 (25.0)
	Constantly	0 (0.0)
Limitations on registration	None	2 (50.0)
	Rare	1 (25.0)
	Now and then	1 (25.0)
	Constantly	0 (0.0)
Limitations when starting the application	None	3 (75.0)
	Rare	1 (25.0)
	Now and then	0 (0.0)
	Constantly	0 (0.0)

(Continues)

TABLE 3 (Continued)

Question	Answer	Frequency (in %)
What problems were there exactly?	Accounts unclear; employee vs. physician	1 (25.0)
What is your overall assessment of the severity of the technical problems?	No problems encountered	2 (50.0)
	Very light	0 (0.0)
	Quite light	1 (25.0)
	Neither light nor heavy	1 (25.0)
	Quite heavy	0 (0.0)
	Very heavy	0 (0.0)
What did you like most about using the digital application?	More flexibility	1 (25.0)
	Time saving	2 (50.0)
	Good operation	1 (25.0)
	Issue of follow-up prescriptions	0 (0.0)
	Chat function	0 (0.0)
	Other	0 (0.0)

Abbr.: SD, standard deviation

effectively supplement conventional consultations when needed or replace them for monitoring chronic dermatologic diseases. The digital concept developed specifically for CSU adressed challenges such as unpredictable disease flare-ups and the need for rapid treatment adjustments. It enabled continous monitoring trough ePROs, including the option of direct and immediate contact with a physician. This specialization likely contributed significantly to participant satisfaction and confidence in the system. Throughout the pilot study, disease control and quality of life remained stable, suggesting that the digital intervention had no negative impact. Feedback also highlighted the potential for time savings and greater flexibility in healthcare delivery - significant benefits for chronic disease management. In addition, the 12-month follow-up period allowed a comprehensive evaluation in the long term.

However, limitations of the pilot study include the small sample size and monocentric design, which limits the generalizability of the results. The lack of a control group makes it difficult to attribute the observed benefits to the digital intervention alone. Minor technical issues indicated areas where ease of use could be improved, particularly in simplifying account setup through email invitations. These issues could make initial contact significantly more difficult, especially for less tech-savvy individuals. In addition, self-reporting carries a risk of bias, as patients' perceptions may not accurately reflect clinical reality.

Comparison with prior work

The results of our pilot study extend the existing literature on teledermatology by focusing on the long-term management of patients with CSU. While previous studies generally emphasize the effectiveness and efficiency of telemedicine approaches in dermatology, our research focuses on the acceptability and ongoing interaction and management of CSU with patient-reported outcomes such as disease control and quality of life.[20,32–37] Especially during the COVID-19 pandemic, studies such as the one by Pathania et al. and Mustafa et al. have shown how teledermatology can improve accessibility and continuity of care by making it possible to maintain high-quality patient care despite social distancing.[38,39] Our research is consistent with the findings of Lascialfari et al., who investigated the effectiveness of telemedicine in monitoring patients with CSU.[40] They showed that telemedicine approaches can enable effective care for this patient group, significantly improving clinical monitoring and management.

Our pilot study builds on these sound findings and goes one step further by examining the specific aspects of patient acceptance and satisfaction and disease control within a digital model of care specifically for CSU. We find that the digital model is not only complementary to conventional treatment but can also be seen as a potentially equivalent alternative in controlled CSU. This is supported by our observations that patients and clinicians reported high acceptance rates with digital care, indicating the practical feasibility and effectiveness of teledermatology in the long-term treatment of CSU and embedding it into everyday clinical practice. In addition, our research highlights important aspects of technical feasibility and user-friendliness that have also been emphasized in previous studies.[41] We were able to show that despite initial challenges in the technical implementation, such as setting up user accounts, the digital platform was successfully implemented and was well received by users.

Overall, our pilot study contributes to the literature on teledermatology by adding important aspects of acceptance and management of chronic diseases such as CSU and provides a valuable framework for future research and practical applications in similar health contexts.

CONCLUSIONS

This pilot study underlines the importance of digital health solutions for treating chronic diseases such as CSU. The high acceptance rate among patients and physicians shows that digital care models can effectively complement traditional treatment methods. The ability of these models to enable regular monitoring and rapid adjustments to treatment could be beneficial in responding to dynamic changes in patients' conditions.

This pilot study provides initial evidence for the integration of digital care concepts into the regular medical treatment of CSU. It encourages further extensive research to understand the long-term impact of these technologies and expand their areas of application in clinical practice. Future studies should focus on validating the effectiveness of these approaches in a broader and more diverse patient population and examining how digital technologies can improve the overall accessibility and quality of dermatology care.

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CONFLICT OF INTEREST STATEMENT

None.

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3.3 Paper III

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Continuously monitoring the human machine? – A cross-sectional study to assess the acceptance of wearables in Germany

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Abstract

Background: Wearables have the potential to transform healthcare by enabling early detection and monitoring of chronic diseases. This study aimed to assess wearables' acceptance, usage, and reasons for non-use. **Methods:** Anonymous questionnaires were used to collect data in Germany on wearable ownership, usage behaviour, acceptance of health monitoring, and willingness to share data. **Results:** Out of 643 respondents, 550 participants provided wearable acceptance data. The average age was 36.6 years, with 51.3% female and 39.6% residing in rural areas. Overall, 33.8% reported wearing a wearable, primarily smartwatches or fitness wristbands. Men (63.3%) and women (57.8%) expressed willingness to wear a sensor for health monitoring, and 61.5% were open

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to sharing data with healthcare providers. Concerns included data security, privacy, and perceived lack of need. **Conclusion:** The study highlights the acceptance and potential of wearables, particularly for health monitoring and data sharing with healthcare providers. Addressing data security and privacy concerns could enhance the adoption of innovative wearables, such as implants, for early detection and monitoring of chronic diseases.

Keywords
wearable, health monitoring, data privacy, user acceptance, chronic disease

Introduction

The prevalence of many diseases is increasing worldwide. There are various reasons for this, including environmental and climate change, as well as unhealthy lifestyles.[1,2] Recent technological advances and the increasing digitalisation of healthcare have the potential to address these challenges. In the dynamic field of healthcare, the importance of wearable technologies for continuous monitoring is constantly increasing. These technologies have the potential to effectively monitor patients, improve diagnoses and optimise therapies by tailoring them to the individual needs of each individual.[3,4] In the present context, smart wearables are electronic devices designed to be worn close to or on the surface of the skin. These devices are capable of continuously collecting, analysing and transmitting data related to various body signals, including vital signs, biomarkers and environmental information.[5–9] An important application of wearable technology is ecological momentary assessment (EMA), which evaluates a person's behaviour and experiences in their natural environment in real time.[10,11] This method provides valuable insights into a person's state of health. Ecological momentary intervention (EMI) uses the data to take timely action and improve patient care through personalised and contextualised health strategies.[10,11] These applications demonstrate the potential of wearable devices to provide adaptive and timely healthcare treatments. Around 28% of the German population used wearables to monitor their physical activity in 2016.[12,13] Wearables are different types of devices such as smartwatches, fitness trackers, rings, hearables and special devices that can collect data via the skin.[14–21] Innovative wearables can capture a whole range of measurement data that goes beyond conventional functions such as step counting or heart rate. One possible application of this technology is, for example, the monitoring of alcohol consumption.[22,23] This enables continuous and non-invasive measurements that provide both healthcare professionals and individuals with valuable information to detect significant changes in health status. In addition, this technology provides an innovative way to address health issues and encourage people to adopt healthier lifestyles. Wearables can be divided into different functional subtypes, such as microneedle patches,[12] electronic trans-epidermal tattoos used for non-invasive cortisol measurement via sweat,[9,12] and e-textiles,[14,24] which are characterized by the integration of sensors into clothing.[15,24] The use of wearables in healthcare practice could support and optimize diagnostic and treatment decisions through the continuous monitoring and processing of data collected on an ongoing basis.[17,24,25] Furthermore, patients can become more involved in the monitoring of their health status, resulting in possible time savings and cost reductions for patients and physicians.[9,26–28] However, studies on the acceptance of wearables for health monitoring in connection with data sharing in the daily routine are limited.

The primary aim of this research study is to investigate the acceptance and usage behaviour of wearables in Germany. The study aims to investigate the willingness of individuals to use wearables for health monitoring, to identify the factors that influence the use of wearables and to examine the associated risks and barriers. In addition, the study aims to capture the demographic characteristics of wearable users and non-users.

Methods

Study design and population

This cross-sectional study adheres to the STROBE statement and guidelines.[29,30] Data collection was conducted from July to September 2022 using a convenience sampling technique. Participants were recruited through a multi-channel approach that involved both online and offline methods. The online questionnaire was disseminated via various websites (e.g., university, forums), as well as popular social media platforms, selected for their high traffic and accessibility. In addition, paper-based questionnaires were distributed at an international fair ("Interforst") that provided access to a diverse group of interested attendees. This venue was part of a health campaign by the German Social Insurance for Agriculture, Forestry, and Horticulture. For this study, the sample size calculation was performed using G-Power 3.1.9.6,[31] with an effect size of 0.2 being specified. The probability of a Type I error was set at $\alpha = 0.05$, while the probability of a Type II error was set at $\beta = 0.2$, resulting in a power of 80%. The total sample size calculated for our study was 788 participants. This study was approved by the ethics committee of this study was approved by the ethics committee of the Technical University Munich (reference number 2022-314-S-NP).

Inclusion criteria and missing values

Inclusion criteria for participation were being aged ≥18 years and written informed consent. Participants who did not provide information on the acceptance of wearables ($n = 93$) were excluded. To ensure data quality, participants who answered less than 80% of the questionnaire were excluded from analyses. For the Poisson regression, a further 12 participants had to be excluded due to missing values.

Study questionnaire

A self-designed questionnaire was used. Questions on the acceptance of wearables were based on previous acceptance studies[32–40] that focussed on digital tools and wearables such as fitness trackers. The selected questionnaires were first translated into German. To ensure that our questionnaire comprehensively covered all relevant aspects of user acceptance, we designed it considering key components from the Technology Acceptance Model (TAM) and the Unified Theory of Technology Acceptance and Use (UTAUT). TAM, developed by Davis et al.,[40] is based on two main determinants: perceived usefulness and perceived ease of use. For our study, these concepts were adapted to assess beliefs about enhancing health monitoring through wearables and the effortlessness of their use. UTAUT, proposed by Venkatesh et al.,[41] extends TAM by including performance expectancy, effort expectancy, social influence, and facilitating conditions. In the context of our study, these constructs helped assess beliefs about the wearables. In the paper by Yang et al.,[35] the acceptance questions based on TAM and UTAUT are tested validated instruments. The questionnaire was reviewed by three authors with expertise in dermatology, public health, and statistics. Prior to the main study, we conducted a pilot test with five randomly selected participants. This step allowed us to gather initial feedback and make minor revisions, such as expanding the answer options for closed questions or the translation. Forty-two questions were divided into four sections:

1. Sociodemographic data and current usage of wearables (Table 1, Figure 1)
2. Usage behaviour of wearables among current users (Table 2, Figure 2)
3. Willingness to share data from wearable and with whom (Figure 3)
4. Willingness to wear wearables for health monitoring in the future (e.g., implants) (Figure 4–6)

Table 1. Characteristics of respondents.

	Total (*n* = 550)	Wearable user (*n* = 186, 33.8%)	Wearables non-user (*n* = 364, 66.2%)	*p*-value
Gender				.025
Male	323	97 (30.0%)	226 (70.0%)	
Female	227	89 (39.2%)	138 (60.8%)	
Age				.661
18 – 25	121	41 (33.9%)	80 (66.1%)	
26 – 35	224	78 (34.8%)	146 (65.2%)	
36 – 45	62	21 (33.9%)	41 (66.1%)	
46 – 55	68	26 (38.2%)	42 (61.8%)	
56 and older	75	20 (26.7%)	55 (73.3%)	
Place of residence				.037
Small town to rural community (<19,999)	306	92 (30.1%)	214 (69.9%)	
Medium-sized town to large town (>20,000)	244	94 (38.5%)	150 (61.5%)	
Physical activity per week (hours)				<.001
< 1	87	19 (21.8%)	68 (78.2%)	
1 < 2	157	49 (31.2%)	108 (68.8%)	
2 < 4	154	48 (31.2%)	106 (68.8%)	
> 4	152	70 (46.1%)	82 (53.9%)	
Salary per month (€)				.069
< 1,000	100	36 (36.0%)	64 (64.0%)	
1,000 < 2,000	96	36 (37.5%)	60 (62.5%)	
2,000 < 3,000	178	46 (25.8%)	132 (74.2%)	
3,000 < 4,000	101	38 (37.6%)	63 (62.4%)	
> 4,000	63	28 (44.4%)	35 (55.6%)	
Missing	12			
Education				.045
Lower than high school degree	208	57 (27.4%)	151 (72.6%)	
High school degree	106	41 (38.7%)	65 (61.3%)	
University/doctoral degree	236	88 (37.3%)	148 (62.7%)	
Reasons for non-use of wearables (multiple responses)				
Data protection risk			36 (9.9%)	
Too expensive			59 (16.2%)	
No benefit in use			184 (50.5%)	
Other (lack of knowledge/interest)			72 (19.8%)	

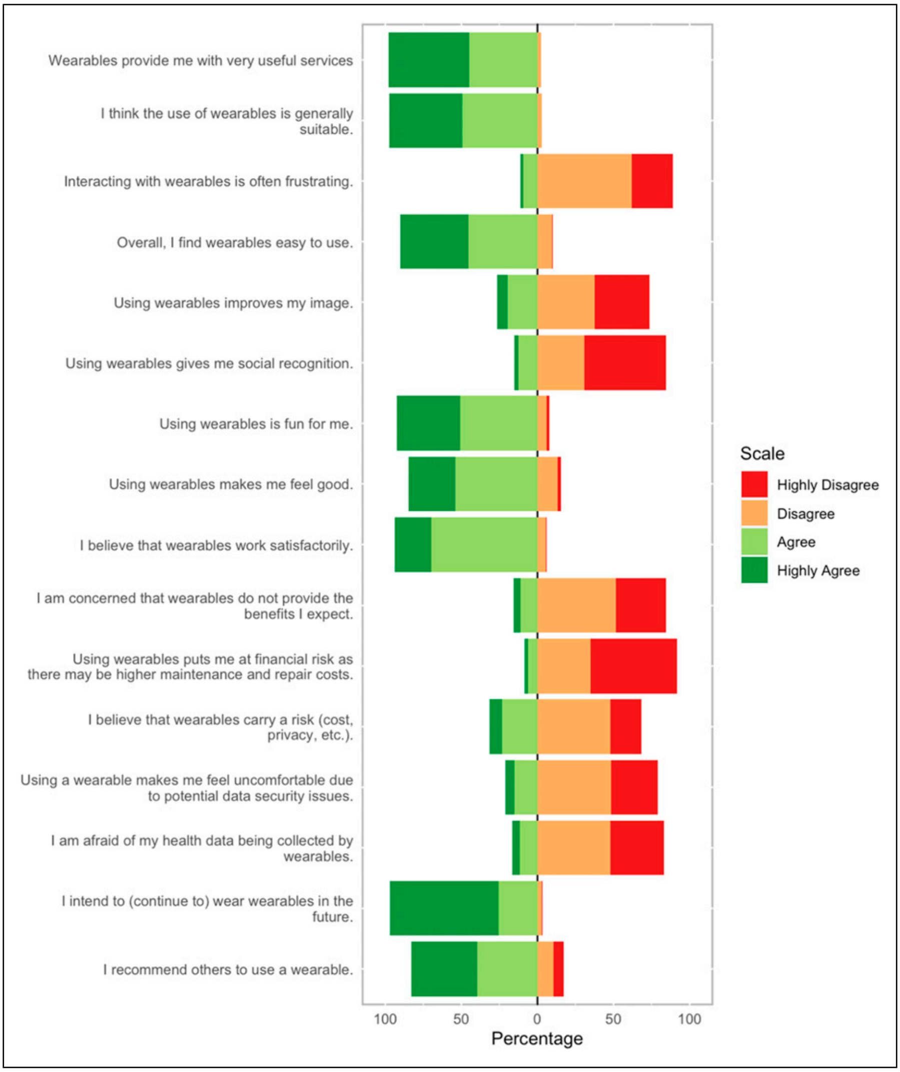

Figure 1. Responses and attitudes among wearable users.

Wearables were defined in the survey as any wearable electronic device that is worn on the body to collect and analyse information about e.g., body signals and/or environmental data.[42] Except for age, variables were predominantly collected as nominal or ordinal variables. The age of the study participants was divided into five age groups to compare between younger and older users: 18 to 25 years, 26 to 35 years, 36 to 45 years, 46 to 55 years, and 56 years and older. Furthermore, study participants were classified according to their place of residence, physical activity, monthly income, and education level. Places of residence were classified as rural communities (<5,000 residents), small towns (5,000–19,999 residents), medium-sized towns (20,000–99,999 residents), and large towns (>100,000 residents). To assess the physical activity per week, we employed a question from the German-validated

Table 2. Frequency of use and type of measurements among wearables users (*n* = 186) as well as associated risk of and barriers to using wearables (*n* = 517).

Question and responses	*n* (%)
What kind of wearable do you use?	
Total respondents	185
Total responses	198[a]
Smart watch	122 (61.6%)
Fitness wristband	60 (30.4%)
Smart ring	8 (4.0%)
Other[b]	8 (4.0%)
If you use a wearable, how often?	
Total respondents	185
Total responses	185
Daily	120 (64.9%)
Several times a week	46 (24.9%)
Once a week	3 (1.6%)
Several times a month	7 (3.8%)
Rarely	9 (4.9%)
How long have you owned your wearable?	
Total respondents	184
Total responses	184
Less than 1 year	39 (21.2%)
Between 1 and 2 years	56 (30.4%)
More than 2 years	89 (48.4%)
What data do you measure with your wearable?[c]	
Total respondents	185
Total responses	772
Pedometry	166 (89.7%)
Pulse	165 (89.2%)
Jogging distance	139 (75.1%)
Calorie consumption	119 (64.3%)
Sleep activity	82 (44.3%)
Breathing rate	40 (21.6%)
Blood pressure	18 (9.7%)
Body temperature	11 (5.9%)
Monitoring of the menstrual cycle	10 (5.4%)
Blood sugar	4 (2.2%)
Other (Electrocardiogram, oxygen saturation)	18 (9.7%)
What risks do you see in the use of wearables?[c]	
Total respondents	517
Total responses	829
Gaps in data protection	261 (50.5%)
No need, as satisfied with current analogue solutions	110 (21.3%)
Too little knowledge about wearables	91 (17.6%)
High costs	81 (15.7%)

(continued)

Table 2. (continued)

Question and responses	n (%)
Do not see any risk	67 (13.0%)
Too little evidence of benefits	66 (12.8%)
Lack of usability	57 (11.0%)
Poor quality	56 (10.8%)
Other[d]	40 (7.7%)
How much would you be willing to pay for a wearable?	
Total respondents	385
Total responses	385
Mean (SD)	165 (±141.53)
0	43 (7.8%)
1 – 50	60 (10.8%)
51 – 100	83 (15.0%)
101 – 200	94 (17.0%)
201 – 300	64 (11.6%)
> 300	41 (7.4%)
Missing	169 (30.5%)

[a] Some participants owned more than one wearable.

[b] Other: Chest straps.

[c] Total sums may exceed 100%, as multiple answers were possible.

[d] Other: Dependence, data validity, permanent monitoring not desirable.

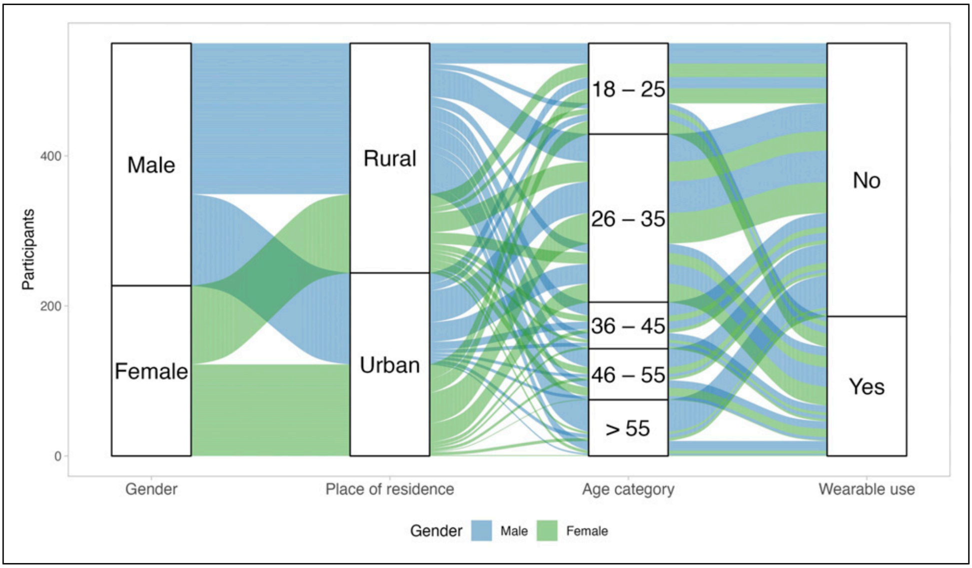

Figure 2. Characteristics of participants and wearable use.

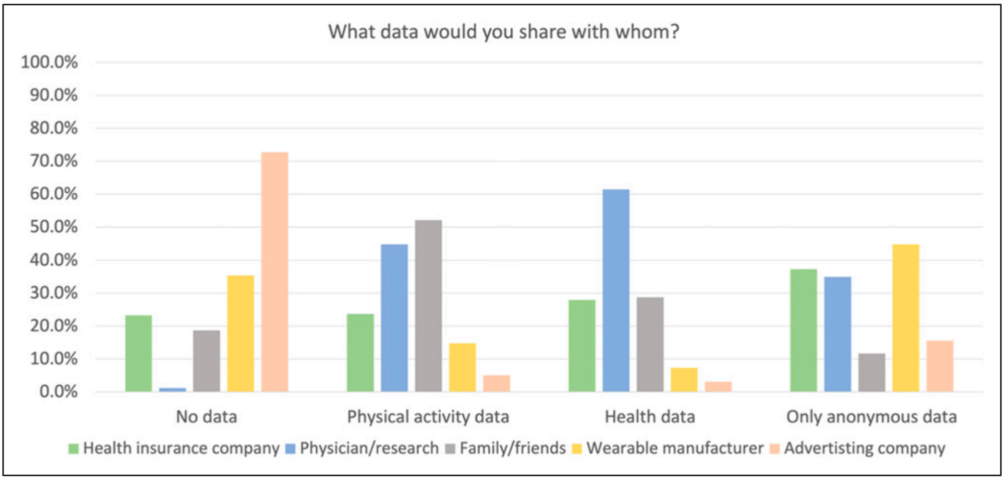

Figure 3. Frequency of willingness to share data measured by wearables for different types of data (total respondents = 257).

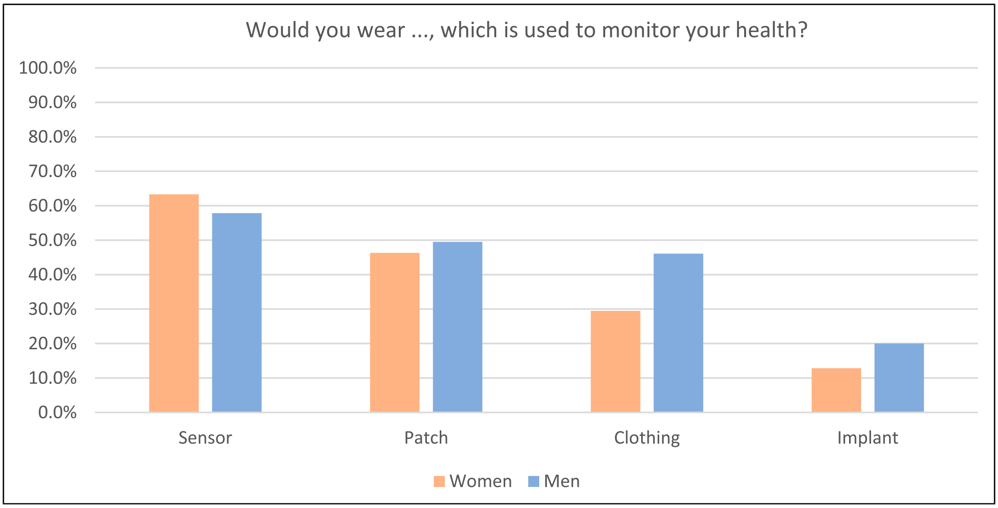

Figure 4. Frequency of willingness to wear various wearables (men and women who responded with "yes" in each category).

version of the European Health Interview Survey (EHIS-PAQ).[43] "How much time in total do you spend on sports, fitness or recreational (leisure) physical activities in a typical week?". For comparison between participants with different physical activity levels, the variable was included with four different categories ("< 1", "1 < 2", "2 < 4", ">4" hours). For comparison between different incomes, the variable "salary per month (€)" was included with five different categories ("<1,000" to ">4,000"). The variable "education level" comprises three categories, including "lower than high school degree", "High school

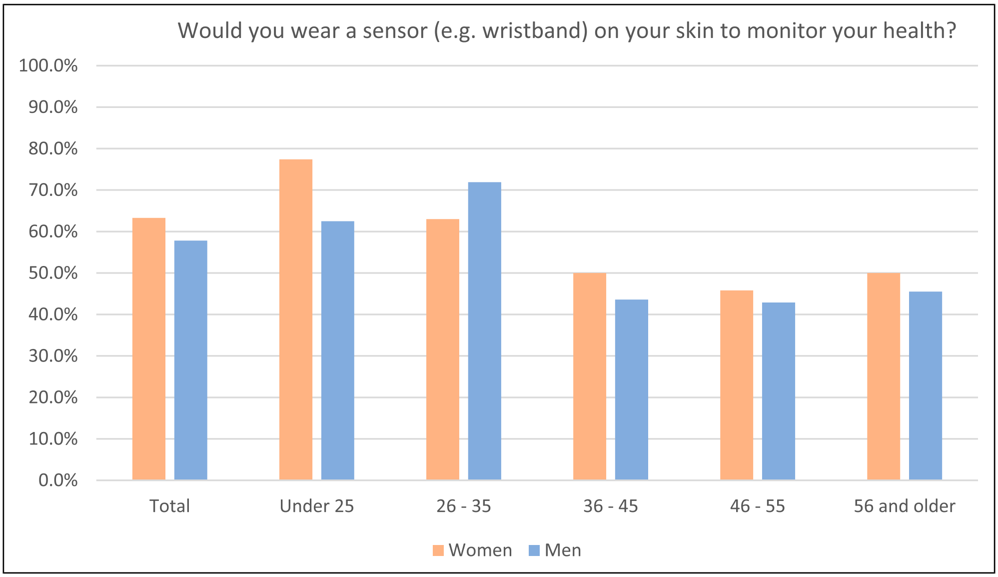

Figure 5. Frequency of willingness to wear a sensor to monitor health (“Yes Responder” of total 257 responders).

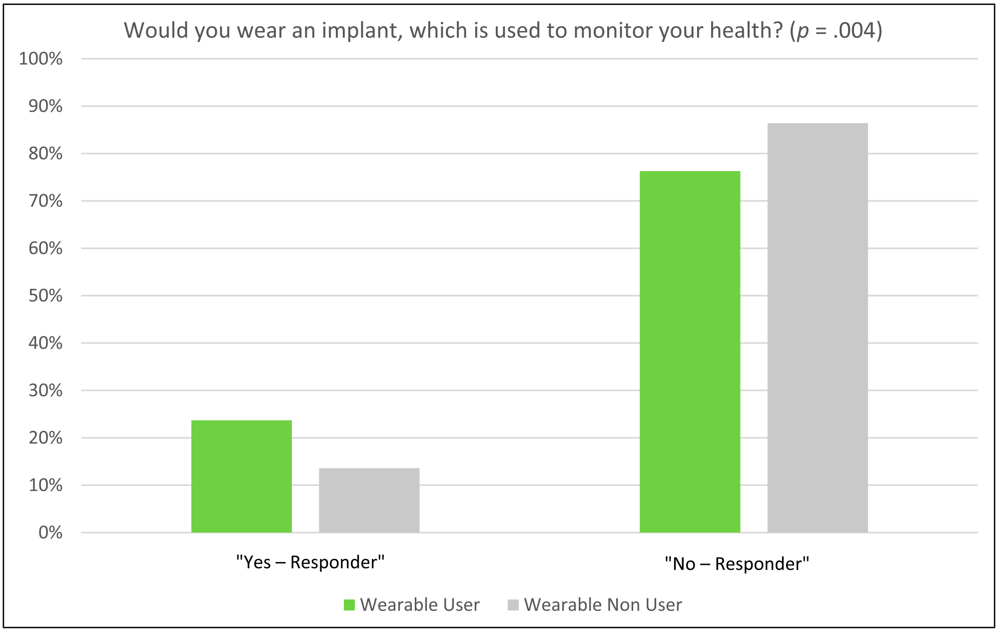

Figure 6. Frequency of willingness to wear an implant to monitor health (“Yes-responder” of total 257 responders).

degree", and "University/doctoral degree". Study data were collected, digitised, and managed using REDCap (Research Electronic Data Capture, Vanderbilt University).[44,45]

Statistical methods

Data management and statistical analyses were conducted using R version 4.2.1[46,47] and IBM SPSS Statistics 28 (IBM Corporation, Armonk, NY, USA). All variables were analysed descriptively using absolute and relative frequencies. Associations between current wearable users and non-users with other variables were tested using Chi-square tests. The Generalized Linear Model (GLM) with a Poisson distribution[48,49] was employed to investigate the association between the use of wearable devices and various predictors, including gender, place of residence, age, physical activity per week, survey location, and monthly salary. Results of the regression model are presented as prevalence ratios (PR) with their 95% confidence interval (CI). The significance level was set to $\alpha = 0.05$.

Sensitivity analysis

To ensure data quality, participants who answered less than 80% of the questionnaire were excluded and not included in the analyses. For the Poisson regression, missing values were excluded from the analysis. Sensitivity analyses were conducted to quantify response biases due to missing information regarding the willingness to use wearables. For this purpose, the acceptance of wearables was calculated for two fictitious scenarios in which all individuals with missing information on the willingness to use wearables were either open (scenario 1) or not open (scenario 2) to using wearables. Another sensitivity analyse All study participants were included in this analysis. In addition, confidence intervals were calculated using the bootstrap method (1000 bootstrap samples, $\alpha = 5$).

Results

Overview

In terms of the survey administration, 235 (42.7%) participants completed the survey using a paper and pencil questionnaire, while 315 (57.3%) participants completed the survey online. Of the 403 online questionnaires initiated, 315 were successfully completed, resulting in an online response rate of 78%.[50]

A total of 550 participants were included in this study (Table 1). Participant age ranged between 18 and 81 years, and the mean age was 36.6 years (standard deviation: 13.9). A total of 186 participants (33.8% of the total sample) reported using wearables, with 39.2% of female respondents and 30.0% of male respondents using wearables ($p = .025$). There was no statistically significant difference in the distribution of wearable users across age groups. For participants aged 18 to 55, 33.9% to 38.2% of participants reported using a wearable depending on the age group ($p = .661$). Although the proportion of participants reporting wearable use decreased to 26.7% in the age Group 56 years and older, the difference was not statistically significant ($p = .661$). There were more wearable users in the medium-sized and large towns (38.5%) than in the small towns and rural communities (30.1%) ($p = .037$).

Regarding physical activity, the largest proportion of wearable users (46.1%) was observed for the category of ">4" hours of exercise per week, which was significantly higher than the percentages observed in the categories with less than 4 h of exercise per week ($p < .001$). Although the proportion of wearable users was highest in the category of monthly income of more than 4,000€ (44.4%), the difference was not statistically significant when compared to categories for lower monthly income (*p* = .069). The proportion of wearable users was higher in the category of "High school degree" (38.7%) and "University/doctoral degree" (37.3%) than in the category of "lower than high school degree" (27.4%) (*p* = .045).

Reasons for non-use

The most prevalent reason, mentioned by 50.5% of non-users, was the perception of no tangible benefit from using wearables. For 16.2% of non-users, cost presented a substantial concern. Approximately 9.9% expressed concerns about data protection and privacy associated with wearables. Furthermore, about 19.8% of non-users fell into the "Other" category, citing various reasons such as a lack of knowledge or interest in wearables.

Usage patterns

Among all 186 wearable users, 122 people owned a smartwatch, 60 people owned a fitness wristband, eight people owned a smart ring, and another eight owned other wearables like chest straps for sports or smart patches for insulin measurement (Table 2). About 90% of users stated that they use their wearable more than once a week, of which 64.5% used it daily. The most common measurements recorded with the wearables were the number of steps walked (89.7%), pulse (89.2%), distance jogged (75.1%), calories consumed (64.3%), and sleep activity (44.3%).

Data sharing and sensor use

Our results show that 61.5% of respondents (158 out of a total of 257 respondents) would share their wearable health or physical activity data (44.7%) with their doctor or a researcher (*n* = 273) (Figure 3). In addition, 42.7% of participants would only share anonymous data with wearable manufacturers. The willingness to wear a health monitoring sensor on the skin was found in 57.8% of men and 63.3% of women among all respondents (Figure 4). (Figure 5) Participants were more willing to wear a (sensor) patch (46.3 % men, 49.5 % women) than a garment with sensors (46.1 % men, 29.5 % women) or a health monitoring implant (20.0 % men, 12.8 % women) (Figure 6). In the wearable user category, the willingness to wear an implant (23.7 %) is higher than in the non-user category (13.6 %) (Figure 6).

Concerns about wearables

Overall, 517 participants responded to the question about the risks and barriers they associate with the use of wearables (Table 2). In most cases, concerns were raised about data protection (50.5%), followed by "no need for wearables" (21.3%), "too little knowledge about wearables" (17.6%), and "high costs" (15.7%). Among all respondents, 13.0% saw no risk at all in using wearables, and 40 respondents provided additional comments specifying the risks they associated with the use of wearables, such as dependence on the device, no confidence in data validity of measurements, and rejection of permanent monitoring.

Factors influencing the use of a wearable

Gender yielded a prevalence ratio (PR) of 1.253 (95% CI: 0.905 to 1.735), indicating a slightly increased, but not statistically significant, prevalence of wearables use among women compared to men (*p* = .174). In terms of physical activity per week, individuals who were physically active for more than 4 h showed a significantly higher prevalence of wearable use (PR = 1.913; 95% CI: 1.142 to 3.203; *p* = .014) compared to individuals with less than 1 h of activity per week. Survey location (online vs paper) showed a significant difference in the use of wearables, with a PR of 1.920 (95% CI: 1.309 to 2.816) for online respondents (Table 3).

Sensitivity analysis

The sensitivity analyses confirmed the robustness of the primary results (Appendix 1). One analysis involved participants with paper-based questionnaires where gender had a significant effect on wearables use (PR = 2.280, 95% CI: 1.213 – 4.289, *p* = .011). Further analysis with online questionnaire participants showed that higher levels of physical activity (>4 h per week) significantly predicted wearables use (PR = 1.917, 95% CI: 1.021 – 3.599, *p* = .043), mirroring the primary findings. No other factors such as place of residence, age or salary showed significant effects.

TAM and UTAUT constructs in wearables acceptance

In the analysis of the constructs of TAM and UTAUT, the reliability assessment for the construct of perceived usefulness resulted in a Cronbach's alpha of 0.798. The construct of perceived ease of use showed a Cronbach's alpha of 0.444. A Cronbach's alpha of 0.62 was determined for the intention to use construct.

Table 3. Results of the Poisson regression with wearable use as a dependent variable and gender, place of residence, age, and physical activity as independent variables.

	PR	95% CI	*p* – value
Gender (Reference: Male)	1.253	0.905 – 1.735	.174
Place of residence (Reference: rural)	1.018	0.736 – 1.409	.912
Age (years) (Reference: Under 25)			
26 – 35	0.986	0.620 – 1.566	.951
36 – 45	1.154	0.625 – 2.129	.648
46 – 55	1.411	0.792 – 2.514	.242
56 and older	1.306	0.702 – 2.432	.399
Physical activity per week (hours) (Reference: <1 h)			
1 < 2	1.247	0.729 – 2.132	.344
2 < 4	1.233	0.720 – 2.112	.385
>4	1.913	1.142 – 3.203	.001
Location of survey, (Reference: At trade fair)	1.920	1.309 – 2.816	<.001
Salary per month (€) (Reference: <1,000)			
1,000 < 2,000	1.089	0.660 – 1.798	.739
2,000 < 3,000	0.864	0.513 – 1.456	.583
3,000 < 4,000	1.145	0.660 – 1.987	.630
>4,000	1.339	0.733 – 2.447	.343

PR: Prevalence ratio, CI: confidence interval

Discussion

Key results

The main objective of our study was to investigate the acceptance and usage behaviour of wearables in the German population. The results showed that 33.8% of participants reported using a wearable - mainly to measure physical activity. In addition, a high proportion of respondents (57.8% of men and 63.3% of women) showed a willingness to use wearables with health monitoring sensors, indicating a positive attitude towards modern health technology.[50] This trend was more pronounced among women and people with higher activity levels, consistent with other studies.[51,52] Individuals who set health-related goals, such as those related to physical activity, will likely find wearables useful for monitoring their progress toward these goals.[50,51,53] Regarding data-sharing preferences, participants showed a clear inclination to share health data with healthcare providers rather than other organisations, highlighting an important aspect of privacy and security in digital health. These aspects align with other results of studies in this field.[8,51,54,55]

Innovative wearables may have great potential for empowering individuals, especially in the medical field, when it comes to diagnosis, behavioural changes, and monitoring of chronic diseases.[7,26,56–58] For example, Hirten et al.[59] showed that wearables can provide important information for patients and can be a suitable approach to routine management of diseases. Our study confirms that people who already use wearables are more open to innovative wearables like implants for monitoring their health.[33,34,50] Our findings regarding the association between physical activity and wearable use are consistent with the findings of the study by Chandrasekaran et al.[51] who reported that people who consider themselves healthier and lead a more active lifestyle are more likely to use a wearable.

Limitations

There are a few limitations in our study that could affect the interpretation of the results. One limitation is the sampling method. As part of the data collection at a fair, it is plausible that this venue attracted individuals with a pre-existing interest in or knowledge of wearable technologies. This selection bias could lead to overestimating the acceptance and usage rates of wearables. Self-report in data collection raises the possibility of recall bias, in which participants do not accurately remember their usage behaviour or preferences, and social desirability bias, which causes them to give responses that they perceive as more favourable or acceptable. In addition, demographic bias, with an average age lower than the national average and a potential over-representation of male participants, could limit the representativeness of the results.[60] The direction of bias created by these limitations is likely to be towards an over-representation of positive attitudes towards wearable technology, and the extent of this bias, although difficult to quantify, could influence important findings.

Interpretation

The Interpretation of these results requires careful consideration of the study objectives and limitations, as well as the context provided by similar studies. The high levels of acceptance and willingness to use wearables for health monitoring found in our study are consistent with global trends in the adoption of digital health technologies.[61–63] However, these findings may represent an optimistic view of wearables uptake, given the methodological limitations of the study. Concerns about privacy and data security are consistent with broader challenges in digital health, highlighting the need for robust data protection measures to encourage wider adoption. Comparisons with similar studies underscore the potential of wearable technologies in healthcare and highlight the common hurdles of privacy and demographic representativeness.[6,9,25,64–67]

Generalizability

To increase the generalizability of the study results on wearables for health monitoring, an extension to the medical context should be considered. Including patients could provide information on how wearables can be used specifically to monitor health conditions and support therapeutic measures. This would enable an understanding of efficient use under the requirements of the healthcare sector (e.g. data protection, reliability). Expanding the study population to include different age groups and socioeconomic backgrounds would also help to develop a more comprehensive understanding of the acceptance and use of wearables beyond the younger, tech-savvy population included in this study.

Conclusion

This study investigated the acceptance and perception of wearables and found that most people have a positive attitude towards wearables. The wearables used were mainly used to monitor physical activity. The high willingness to use wearables for continuous health monitoring and to share health data with healthcare providers offers great potential. However, secure digital solutions are needed to address concerns such as data security. Further research is needed to learn more about the acceptance and benefits of wearables in medicine, e.g., microneedles or implants, which offer great potential for continuous monitoring and improvement of patient care in the context of personalized medicine.

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Authors' contributions

M.H. conceived and designed the analysis, did the data collection, performed the analysis, and wrote the paper. H.W. supported the data collection and analysis and reviewed the paper. A.Z. conceived and designed the analysis and reviewed the paper. T.B. reviewed the paper.

Declaration of conflicting interests

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Ethical statement

Ethical approval and consent to participate

The study was reviewed and approved by the responsible ethics committee of the Faculty of Medicine at Technical University of Munich (2022-314-S-NP) and was conducted in accordance with national law and the Declaration of Helsinki. Patients' informed consent to participate was obtained prior to the study.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplemental Material

Supplemental material for this article is available online.

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3.4 Paper IV

Original Paper

Tracking Public Interest in Rare Diseases and Eosinophilic Disorders in Germany: Web Search Analysis

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Abstract

Background: Eosinophilia and hypereosinophilic syndrome (HES) are rare disorders grouped under the term hypereosinophilic disorders. They are diagnosed based on an increased number of eosinophils. They can also cause serious symptoms, including skin, lung, and gastrointestinal problems. These disorders are very rarely recognized due to their rarity and misdiagnosis.

Objective: This study analyzes public interest in hypereosinophilic disorders using data on internet search volume in Germany between 2020 and 2023. Objectives include identifying frequently searched terms, evaluating temporal trends, analyzing seasonal patterns, evaluating geographic differences in search behavior, and identifying unmet information needs and frequently searched risk factors.

Methods: A retrospective analysis using Google Ads Keyword Planner gathered monthly search volume data for 12 German terms related to hypereosinophilic disorders. These terms were selected based on their medical relevance and common usage identified from medical literature. Data were analyzed descriptively, with trends, seasonal variations, and geographical distributions examined. Chi-square tests and correlation analysis assessed statistical significance.

Results: A total of 178 keywords were identified, resulting in a search volume of 1,745,540 queries. The top keyword was "eosophile," a misspelling, followed by "eosinophilia" and "HES." The main categories included "Eosinophilia," "Eosinophils," and "Churg-Strauss syndrome." Temporal analysis showed seasonal growth in search volumes, peaking in January 2023, with higher interest during winter. Geographical analysis showed regional variations.

Conclusions: This research shows a growing public interest in eosinophilic diseases, reflected by a steadily increasing search volume over time. This is particularly evident in searches for basic definitions and diagnostic criteria, such as "eosinophils" or "symptoms of eosinophilic diseases." This increase in search volume, which peaked in January 2023, indicates an increased interest in accurate and readily available information for rare conditions.

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Keywords: hypereosinophilia; eosinophilia; public health informatics; web search analysis; rare diseases

Introduction

Background

Hypereosinophilic diseases are defined as the presence of persistently elevated eosinophil counts that can cause tissue damage and inflammation of various organs, including the skin, lungs, or gastrointestinal tract [1,2]. These diseases cause symptoms such as severe itching, breathing problems, and gastrointestinal complaints [1,3-5]. Some severe forms of these diseases are characterized by hypereosinophilic syndrome (HES), in which there is tissue infiltration of eosinophils above accepted thresholds for eosinophilia, which can lead to abnormal damage to organ systems [6-9].

Hypereosinophilic disorders can have a significant impact on the individual, but they are often unrecognized and misdiagnosed, mainly due to their rarity and the heterogeneity of clinical presentation [10-13]. Diagnosis is typically based on the exclusion of other causes of eosinophilia (eg, allergic diseases or parasitic infections) and histopathological and immunohistochemical studies, permitting classification in the following subtypes: myeloproliferative (M-HES), lymphocytic (L-HES), idiopathic (I-HES), and chronic eosinophilic leukemia not otherwise specified (CEL-NOS). [1,10]. Treatment is based on subtype; corticosteroids plus systemic immunosuppression may be used, as well as cytotoxic agents (hydroxyurea and methotrexate), tyrosine kinase inhibitors (imatinib for M-HES), or targeted biologics (mepolizumab) [4]. Prognosis for HES varies; mortality rates can be as low as 7% to 10% for some subtypes, while mortality rates for CEL-NOS can be as high as 33% over a period of 19-90 months [4].

It would be helpful to understand how the public navigates information about hypereosinophilic disorders to identify how this process could be altered to lead to successful diagnosis and treatment [4,14]. Digital technologies have developed to the extent that there is widespread access to online health information [15]. Patients are also more likely to turn to the internet to research their health-related questions, starting with a search for their specific symptoms and continuing with possible underlying causes and treatment plans [16-21]. Therefore, this shift from patients becoming passive recipients of medical advice to active participants in health care has seen a steep increase.

The patient journey—the patient experience from symptom awareness to treatment itself—has become more fluid and individualized [15]. This process may involve many phases, such as seeking signs of symptoms, possible diagnoses, or treatment options. These phases are dependent on individual, emotional, and contextual factors and lead to a series of nonlinear pathways through the health care system. These pathways are particularly convoluted in hypereosinophilic disorders [22] due to changing patient presentations, providers, diagnostic challenges, and lack of public and clinical awareness.

The Google Ads Keyword Planner is a valuable tool that allows users to analyze public interest and engagement with health topics using search volume data [23,24]. This approach allows researchers to monitor real-time data on public interest, identify trends in information tracking, and analyze spatial and temporal variations in interest [25-27]. In contrast, Google Trends provides a broader view of relative interest over time, offering insights into how frequently terms are searched relative to all searches made on Google. While Google Trends normalizes search volume data and provides general trends, it lacks the detailed search volume metrics that Google Ads Keyword Planner offers. Unlike social media, where shared information may be curated and filtered [28], search queries provide a more direct and unfiltered view of individuals' health concerns and information needs. This perspective is particularly relevant for rare and underrecognized conditions such as hypereosinophilic disorders, where traditional sources of public health data may be limited.

Objective

Given the rarity and diagnostic challenges of hypereosinophilic disorders, understanding how the public seeks information about these conditions can provide valuable insights into awareness gaps and unmet informational needs. Therefore, the primary aim of this study is to analyze public interest and information-seeking behavior related to eosinophilic disorders in Germany, using Google search data from 2020 to 2023. By examining trends, seasonal patterns, and geographical variations in search volumes, this study seeks to identify key areas of concern and opportunities to enhance public education on these underrecognized conditions.

Methods

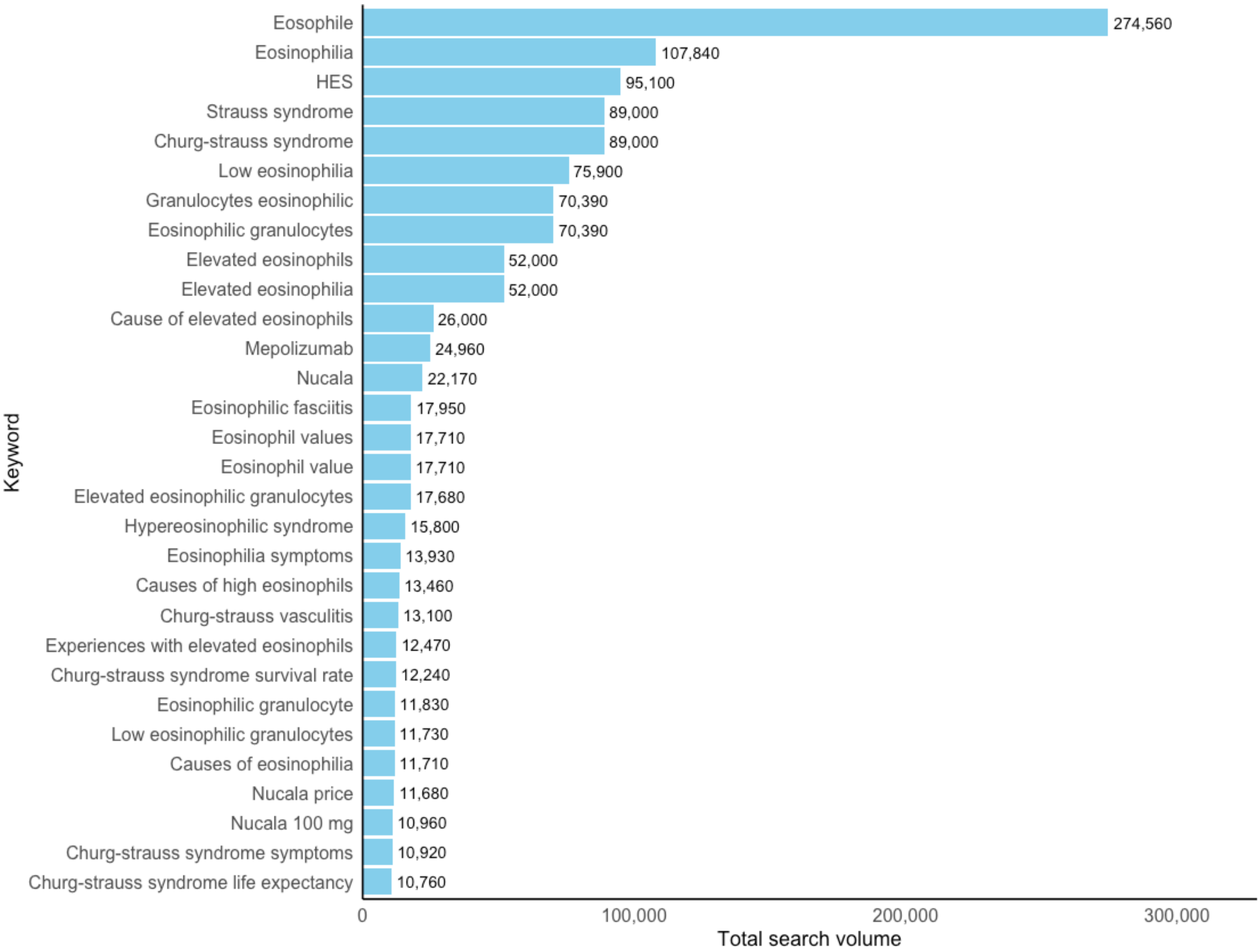
Study Design and Data Collection

In this retrospective analysis, the Google Ads Keyword Planner was used to gather monthly search volume data. Although initially designed for marketing campaigns, this tool effectively provides monthly web search volume data (ie, monthly number of web searches) for research purposes [27,29-31]. To determine the search volume in a specific area, relevant search terms are entered into the planner. The language and geographical settings can then be configured, and the most relevant keywords and phrases for the topic entered.

Search Terms and Keyword Identification

For this study, 12 German search terms related to hypereosinophilia and associated conditions were entered (Figure 1). The goal was to obtain related keywords and phrases and their monthly search volume in Germany between January 2020 and December 2023. The search terms were "Hypereosinophilia," "Hypereosinophilic Syndrome," "Hes," "Eosinophilia," "Blood Eosinophilia," "Reactive Eosinophilia," "Tissue Eosinophilia," "Eosinophilic Granulocytes," "Eosinophilic Syndrome," "FIP1L1," "Mepolizumab," and "Nucala."

Figure 1. Total search volume for the top 30 keywords (2020-2023). HES: hypereosinophilic syndrome.



The 178 keywords were reviewed for relevance to hypereosinophilia and grouped inductively into categories based on their association with the disease, clinical subtypes, treatments, diagnostic markers, and related conditions: “Eosinophilia,” “Eosinophils,” “Churg Strauss Syndrome,” “HES,” “Eosinophilic Granulocytes,” “Nucala,” “Mepolizumab,” “Eosinophilic Fasciitis,” “Eosinopenia,” “EGPA (Eosinophilic Granulomatosis with Polyangiitis),” “Eosinophilic Granulomatosis,” “Blood Eosinophilia,” and “FIP1L1.”

Categories for recurring topics were further subdivided into subcategories (eg, diagnostic information). For each keyword, only one subcategory was assigned. The data were analyzed descriptively.

Geographical Scope

The search volume in all of Germany was examined. Search data for all 16 German federal states and cities were analyzed. Cites were selected based on their population and geographic location in order to obtain a representative overview of all of Germany. For a more in-depth view, cities that are of particular interest due to their unique demographics or health-related infrastructure were also included.

The predefined list of cities included in the study comprised cities that are well distributed across the country and include both large and small cities: Bad Bramstedt, Berlin, Bremen, Cologne, Dortmund, Dresden, Erfurt, Frankfurt, Freiburg, Giessen, Hamburg, Hanover, Heidelberg, Jena, Kassel, Kiel, Kirchheim Teck, Leipzig, Magdeburg, Mainz, Mannheim, Munich, Nuremberg, Regensburg, Rostock, and Stuttgart.

Statistical Methods

To summarize and visualize the search volume data, we used descriptive statistics. Means and measures of dispersion (SD and IQR) were calculated for the monthly search volumes in different categories and subcategories. Frequencies and percentages were used to describe the distribution of searches among the identified categories. We applied a time series decomposition to monthly search volume data since January 2020, using the seasonal and trend decomposition using Loess to extract seasonal, trend, and remainder components. This allowed us to quantify seasonal patterns with CIs and to measure the variability in the data.

Temporal and Geographical Analysis

Trends during the study reporting period (January 2020 to December 2023) were assessed using a time series analysis. We applied seasonal decompositions to locate and quantify seasonal fluctuations in search volume (seasonal decomposition of time series). Search queries were processed for each federal state and city, and the search queries per 100,000 inhabitants were calculated to analyze the geographical distribution of the search volume. This allowed us to identify areas with increased or decreased search activity related to eosinophilic disorders.

Statistical Testing

Chi-square tests were conducted to assess the significance of differences in search volume between categories and regions. This test was useful for determining whether the distribution of searches across categories was statistically different from what would be expected by chance.

Correlation Analysis

Prior to statistical analysis, we tested the normality of the search volume data using the Shapiro-Wilk test. The results indicated a normal distribution ($P=.89$). A chi-square test was conducted to examine the associations between search volumes and different regions. This analytical strategy helped to explore potential demographic or health-related factors associated with higher search activity. In this map, each tile represents a search term category, and red areas highlight regions with high relative search volume, resulting in an easy-to-understand heat map visualization that makes it simple to see how interest is distributed across regions in the categories. The intensity of the displayed color reflects the number of searches per 100,000 people on average, with light colors indicating minimal search interest and dark colors indicating higher search interest.

Identification of Significant Rises

We calculated z scores for each time point to detect significant increases in search volume. The z score was computed by subtracting the mean search volume and dividing by the SD. Points with z scores greater than 2 were marked as significant rises, indicating substantial deviations from the average trend.

Validation of Methodology

To ensure the validity of the methodology, the search volumes from the Google Ads Keyword Planner were compared with data from Brandwatch (Giles Palmer) [32]. Brandwatch analyzes mentions on various platforms such as Facebook Public, forums, internet-based news, and X (formerly Twitter). This comparison was used to verify whether the identified peaks and trends in search volume can also be found on other platforms and whether similar patterns exist across multiple sources. This ensured that the observed trends are consistent and not distorted by the commercial orientation of Google Ads.

Software and Tools

All statistical analyses were performed using R (version 4.1.2; R Core Team). Spatial data analysis used *rnaturalearth* packages, and visualizations were created with *ggplot2* [33-40].

Ethical Considerations

As the study was based on publicly accessible Google search terms, there was no requirement for institutional review board approval, and informed consent was not applicable.

Results

Overview of Search Volume

Overall, 178 keywords related to hypereosinophilia were identified, resulting in a search volume of 1,745,540 queries from January 2020 to December 2023.

The analysis of search volumes for keywords related to eosinophilic disorders revealed several key insights. Interestingly, the top keyword was “eosophile” with 274,560 searches, despite being a misspelling and lacking medical meaning (Figure 1). This indicates a potential gap in public understanding or a common typographical error. Following this, the correct medical term “eosinophilia” had 107,840 searches, and “HES” had 95,100 searches. Other top keywords with the highest search volumes included “Churg-Strauss syndrome” and “low eosinophilia” (Table 1).

Table 1. Top 30 unique keywords for each main category and subcategory.

Main category	Subcategory	Frequency of unique keywords, n
Eosinophilia	Diagnosis	18
Eosinophil granulocytes	Diagnosis	15
Eosinophils	Diagnosis	13
Eosinophilia	Causes/associated diseases	11
HES[a]	General information	11
Nucala	General information	11
Mepolizumab	General information	10
Eosinophilia	Symptoms	7
Churg-Strauss syndrome	Treatment	5

Main category	Subcategory	Frequency of unique keywords, n
Churg-Strauss syndrome	General information	5
Eosinophilic fasciitis	General information	5
Eosinophilia	General information	5
Churg-Strauss syndrome	Causes/associated diseases	4
Eosinophilia	In animals	4
Churg-Strauss syndrome	Diagnosis	3
Churg-Strauss syndrome	Symptoms	3
Eosinopenia	General information	3
Nucala	Dosage	3
Nucala	Costs	3
Blood eosinophilia	General information	2
Churg-Strauss syndrome	Localization	2
Churg-Strauss syndrome	Survival	2
EGPA[b]	Treatment	2
Eosinopenia	Diagnosis	2
Eosinophil granulocytes	Causes/associated diseases	2
Eosinophilia	Treatment	2
Eosinophils	Causes/associated diseases	2
HES	Treatment	2
HES	Symptoms	2

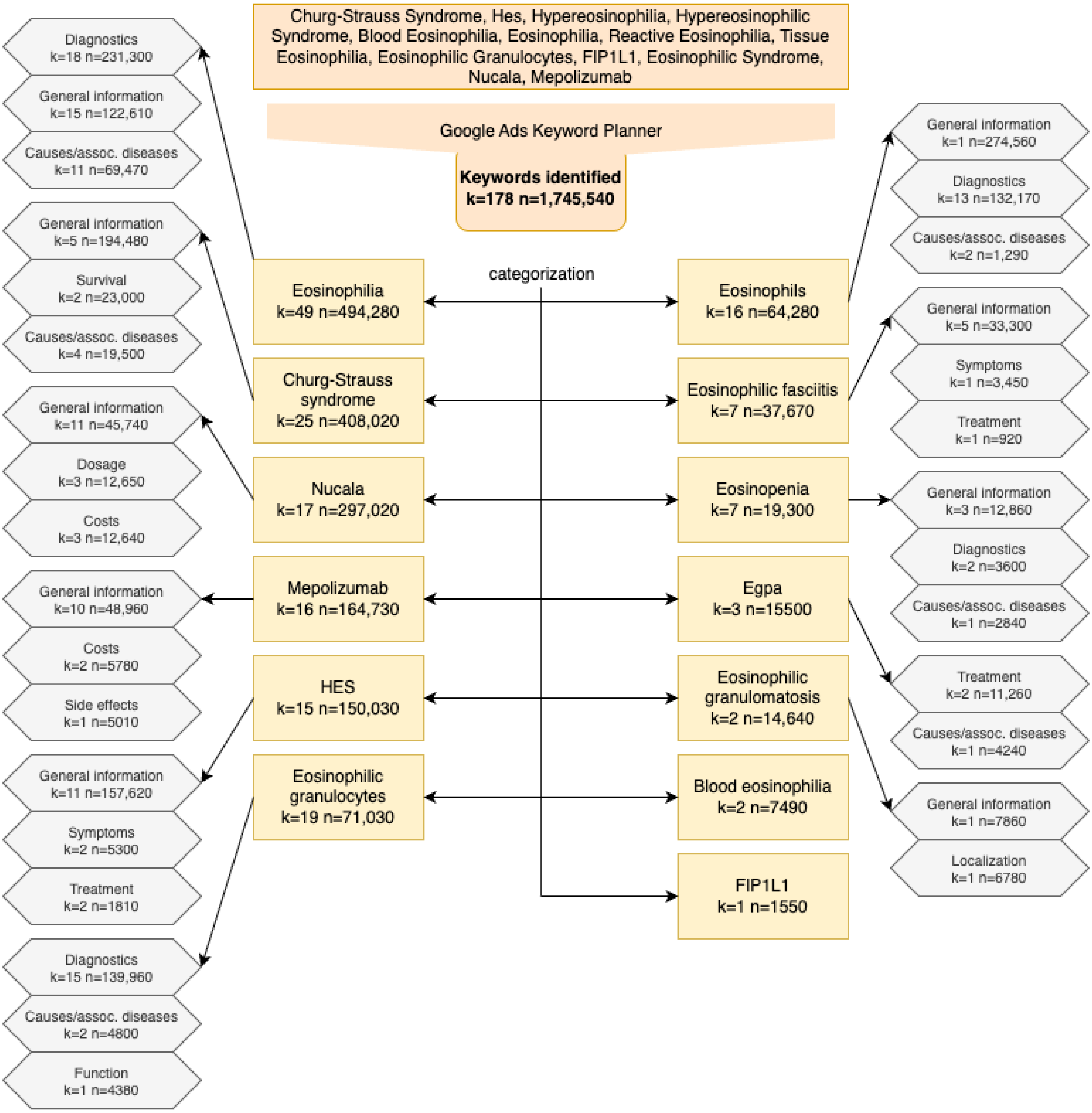
[a] HES: hypereosinophilic syndrome.

[b] EGPA: eosinophilic granulomatosis with polyangiitis.

Categorization of Search Terms

These keywords were assigned to the following categories (Figure 2). In terms of main categories, “Eosinophilia” topped the list with a total of 494,280 searches, accounting for 28.32% of the total search volume. This was followed by “Eosinophils” with 408,020 searches (23.38%) and “Churg-Strauss syndrome” with 297,020 searches (17.02%). These categories highlight the primary areas of interest among the public.

Figure 2. Flowchart of data generation and content categorization. This flowchart illustrates the process used to gather and categorize the keywords related to eosinophilic disorders. First, relevant search terms were identified based on their medical significance and prevalence in the literature. Next, data were collected from Google Ads Keyword Planner, which provided monthly search volume information for each term. The identified keywords were then grouped into broad categories such as "Eosinophilia," "HES," "Churg-Strauss Syndrome," and others based on their relevance. Within these categories, further subcategories were created, focusing on specific topics such as diagnosis, symptoms, treatment, and related diseases. For clarity, only the top three subcategories are listed when more than three subcategories exist. HES–related web searches in Germany from 2020 to 2023 were analysed. If no subcategory was created, the group was too small or only general information was searched for. assoc.: associated; EGPA: eosinophilic granulomatosis with polyangiitis; FIP1L1: gene involved in hypereosinophilia; HES: hypereosinophilic syndrome; k: number of keywords; n: number of searches.

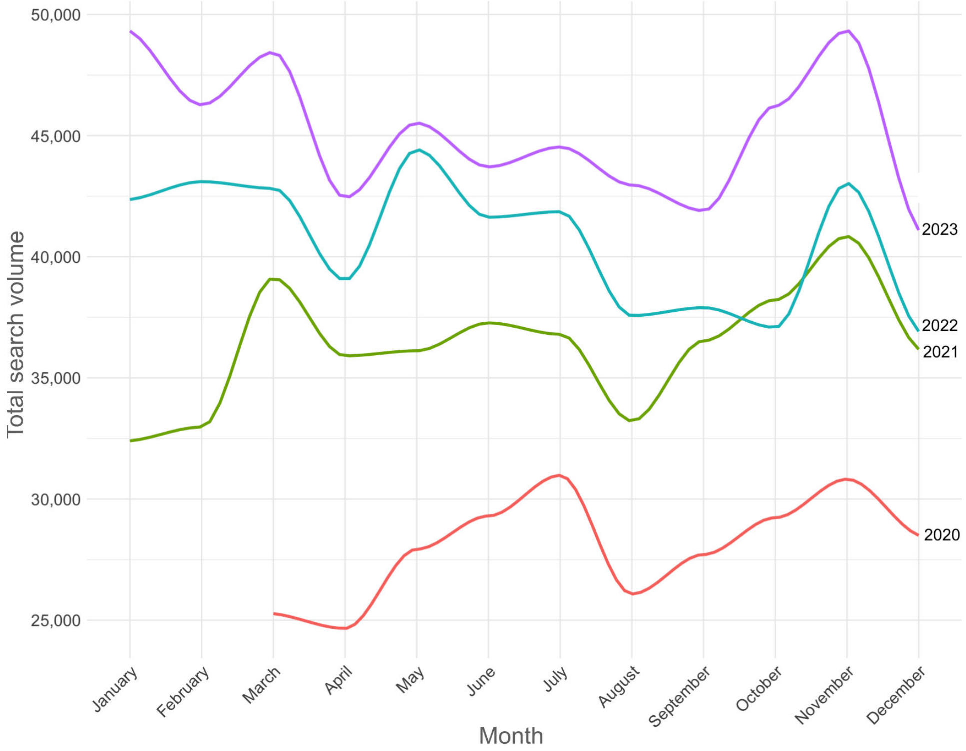


Within these main categories, the top subcategories provided further insight into specific areas of interest (Figure 2). For "Eosinophilia," the most searched subcategory was "diagnosis" with 231,300 searches (13.25% of the total search volume), followed by "general information" with 122,610 searches (7.02%), and "causes/associated diseases" with 69,470 searches (3.98%). For "Eosinophils," the leading subcategories were "general information" (274,560 searches, 15.73%), "diagnosis" (132,170 searches, 7.57%), and "causes/associated diseases" (1290 searches, 0.07%). In the "Churg-Strauss syndrome" category, "general information" led with 194,480 searches (11.14%), followed by "survival" with 23,000 searches (1.32%) and "causes/associated diseases" with 19,500 searches (1.12%).

Temporal Trends in Search Volume

From March 2020 to December 2023, eosinophilic disorders exhibited significant growth, peaking in January 2023 at 49,320 queries (Figure 3). Seasonal patterns reveal higher interest during winter months and slight declines in summer, with a consistent yearly increase in overall search volumes. This trend highlights rising public awareness and interest in eosinophilic disorders over time (see also Figure S3 in Multimedia Appendix 1) .

Figure 3. Total search volume by month over 4 years.

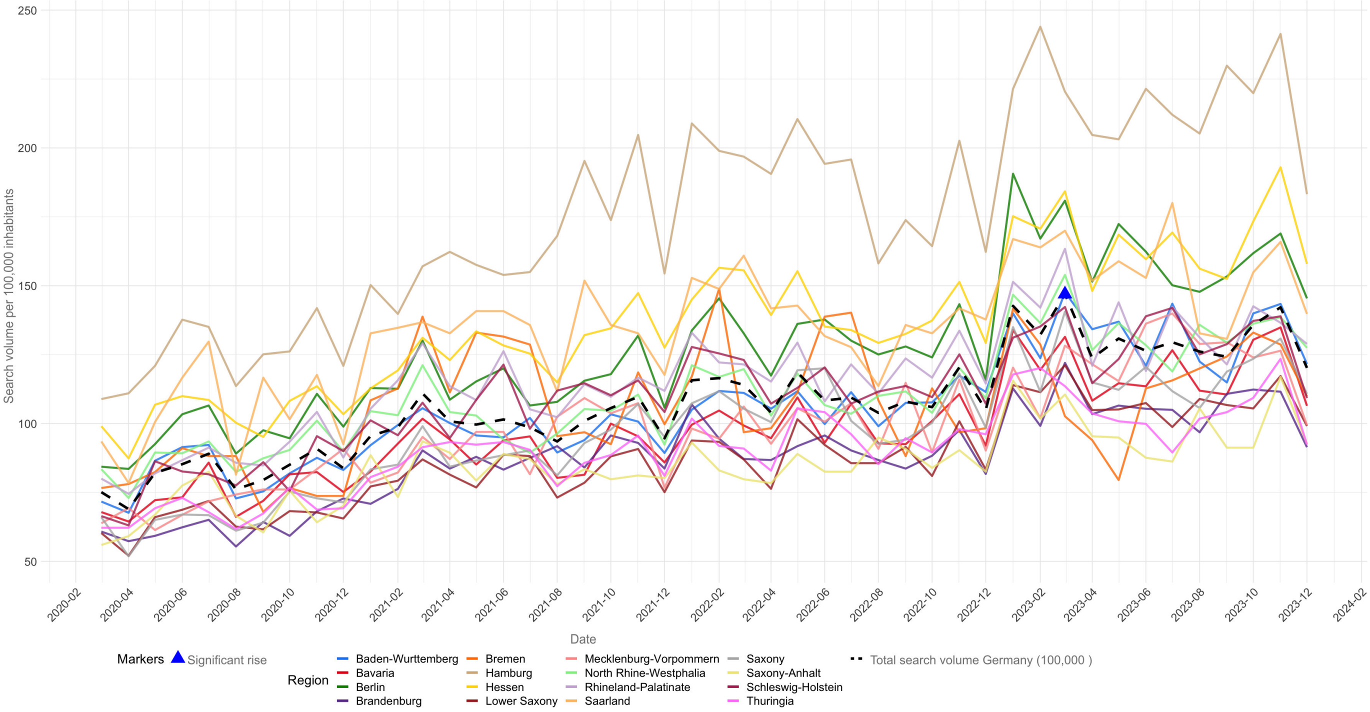


The decomposition of the search volume time series revealed key patterns (Figures S5 and S6 in Multimedia Appendix 1), with Figure S5 in Multimedia Appendix 1 outlining the seasonal and trend decomposition using Loess breakdown into seasonal, trend, and remainder components, and Figure S6 in Multimedia Appendix 1 confirming the seasonal estimates' reliability through diagnostic plots and CIs. The seasonal component showed periodic fluctuations, with notable peaks and troughs, such as a peak in March 2020 (2889) and a low in December 2020 (–4165). This indicates regular cyclical variations in search volume. The trend component exhibited a consistent upward trajectory, increasing from 24,925 in March 2020 to 46,654 by December 2023, suggesting sustained growth in search interest. The remainder component displayed random fluctuations, reflecting irregular variations not explained by the seasonal or trend components. CIs for the seasonal component showed variability, particularly in March 2020, with intervals ranging from –1687 to 7467. Over time, these intervals became narrower, indicating more precise seasonal estimates.

Geographic Distribution

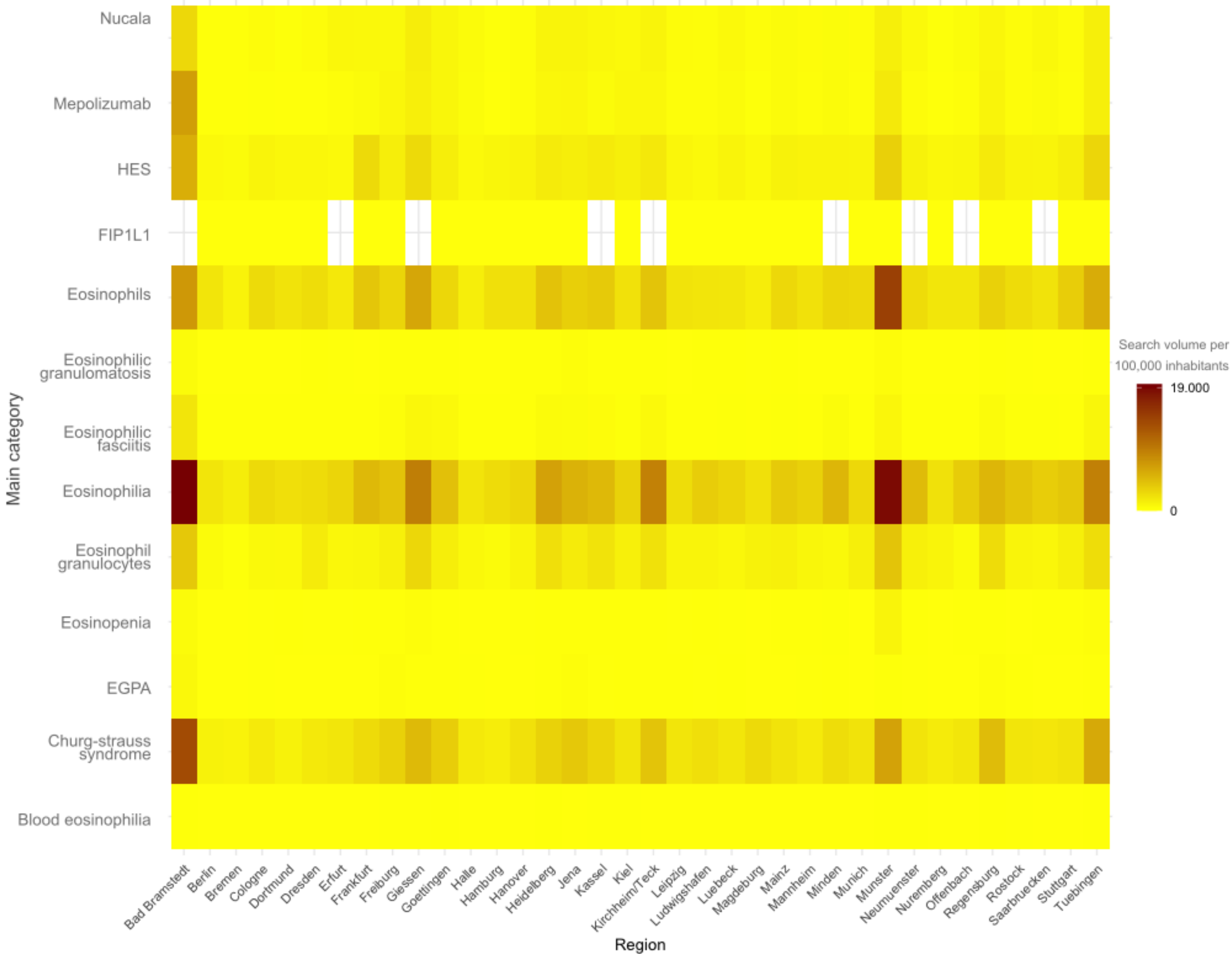
From March 2020 to December 2023, the total search volume per 100,000 inhabitants in Germany showed notable variations (Figure 4 and Figure S1 in Multimedia Appendix 1). Nationally, the peak search volume was 147 per 100,000 inhabitants in March 2023, and the lowest was 69 in April 2020. At the state level, Hamburg recorded the highest peak of 244 searches per 100,000 inhabitants in February 2023. In contrast, Saxony-Anhalt's peak was 117 in November 2023. Seasonal patterns were observed, with increased search volumes across most regions at the start and end of the year. The lowest volumes generally occurred in April 2020 across various states, reflecting consistent national trends.

Figure 4. Total search volume over time per 100,000 inhabitants for Germany and by state.



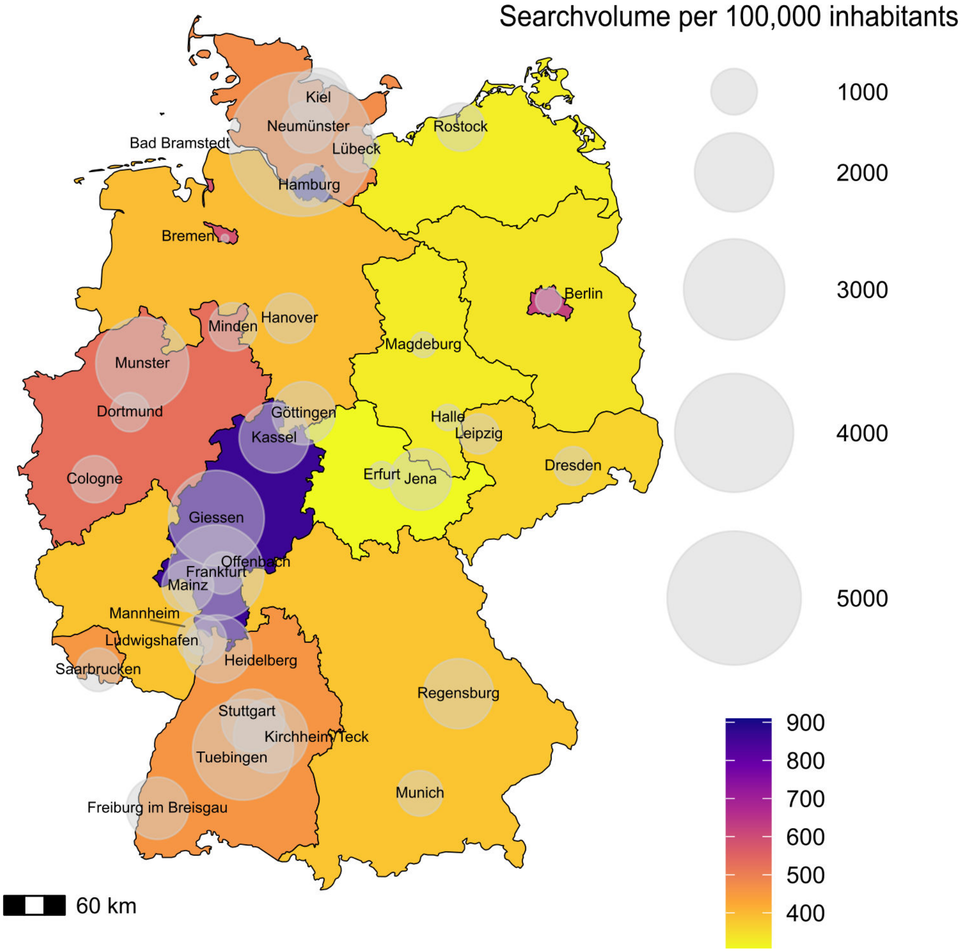
The heatmap (Figure 5 and Figure S4 in Multimedia Appendix 1)) illustrates the search volumes per 100,000 inhabitants across the different German cities. “Eosinophilia” exhibits the highest search volume in Bad Bramstedt with 19,523, while Bremen shows the lowest with 1513. Similarly, for “Churg-Strauss syndrome,” Bad Bramstedt has the highest value at 13,562, compared with Bremen’s 1043. For medications such as “Mepolizumab” and “Nucala,” the highest values are also in Bad Bramstedt (7004 and 2832, respectively), with Bremen having the lowest (207 and 218, respectively). Other cities such as Munster and Tuebingen also display high search volumes, particularly for “eosinophils” (14,529 in Munster) and “Churg-Strauss syndrome” (6154 in Tuebingen).

Figure 5. Search volume per 100,000 inhabitants for key categories across regions in Germany from 2020 to 2023. EGPA: eosinophilic granulomatosis with polyangiitis; FIP1L1: gene involved in hypereosinophilia; HES: hypereosinophilic syndrome.



The analysis of the geographical distribution of the total 4-year search volume for the category “HES” per 100,000 inhabitants only shows remarkable differences across different regions and cities (Figure 6). Hamburg has the highest search volume at 854, followed by Hessen with 805. Thuringia, Saxony-Anhalt, and Mecklenburg-Vorpommern have the lowest volumes at 304, 318, and 327 per 100,000 inhabitants, respectively. Among cities, Bad Bramstedt has the highest search volume at 5738 per 100,000 inhabitants. Tübingen, Giessen, and Frankfurt follow with 2989, 2736, and 2719 respectively. Münster reports 2600 searches, Kirchheim Teck reports 1825, Kassel reports 1666, and Regensburg reports 1665. Heidelberg, Göttingen, Stuttgart, and Freiburg im Breisgau show volumes of 1598, 1441, 1433, and 1413, respectively. The lowest search volumes are in Erfurt, Halle, Berlin, and Magdeburg with 690, 683, 680, and 676, respectively, and Bremen has 587 searches per 100,000 inhabitants.

Figure 6. Search volume per 100,000 inhabitants for the "HES" category by region. HES: hypereosinophilic syndrome.



Validation of Search Volume Trends With External Data Sources

To validate the findings from Google Ads Keyword Planner, we compared them with data from a platform [32] that analyzes mentions across social media, forums, internet-based news, and X (formerly Twitter) (Figure S2 in Multimedia Appendix 1). The data revealed notable peaks in January 2023, particularly in internet-based news, and a peak in October 2022 for forum mentions. These trends aligned with the spikes observed in the Google Ads search volume data, supporting the hypothesis that the increases in search activity are reflected in broader public discussions, indicating genuine rises in interest about hypereosinophilic disorders."

Correlation Analysis

The chi-square test result was highly significant ($P<.001$), indicating a strong association between the categories of search terms and the regions after normalization per 100,000 inhabitants. This suggests that the frequency and type of searches for HES–related information are significantly influenced by regional factors (Table S1 in Multimedia Appendix 1).

Identification of Significant Rises

Significant rises in search volume are marked with blue triangles in Figure 4. These were detected using z scores, indicating periods where the search volume increased substantially beyond typical variations. Notably, in March 2023, there was a significant rise in search volume, reaching 147 per 100,000 inhabitants, well above the average with a z score of 2.08. This points to a notable event or increased interest during this period, potentially indicating a surge in public concern or awareness about the topics searched.

Discussion

Principal Findings

From March 2020 to December 2023, a total of 1,745,540 search queries on eosinophilic diseases were documented, suggesting a high level of public interest in eosinophilic diseases in Germany. The increasing number of searches conducted, particularly during the winter months, may indicate a growing public interest in rare diseases, possibly due to external influences (eg, seasonal worsening of symptoms and increased media coverage) or displacement effects on search engine suggestion lists. It is striking how often people enter search terms incorrectly, such as "eosophile," which accounted for 274,560 search queries, suggesting gaps in the public's understanding of medical terminology. The frequent misspelling of terms indicates a barrier to finding correct medical information. These spelling mistakes show that there are gaps in the public's knowledge of medical terms, which also points to the need for digital literacy campaigns. Raising awareness and educating the public about the correct terminology can help improve the search for information and support self-education, especially with regard to rare diseases.

Regional differences in search volume suggest that cities like Hamburg, Bad Bramstedt, and Freiburg show higher engagement, likely due to the presence of specialized health centers and greater access to medical information. In comparison, Saxony-Anhalt and Bremen show a lower search volume because there are fewer specialists in these regions and consequently less awareness of the disease. These rates may vary depending on disease prevalence and regional health campaigns, as indicated by the peak in January 2023. Future studies should investigate how access to health care, disease prevalence, and regional campaigns may impact public interest in rare diseases. Interestingly, the most common subcategory for searches related to the broader topic of eosinophilia was diagnosis, suggesting a desire among the public to learn more about the identification and symptoms of eosinophilic disorders. This suggests that those searching for such terms may not yet have been diagnosed and are looking for possible causes of their symptoms. The spike to 49,320 searches in January 2023 may be the result of public health campaigns or media coverage and illustrates how external events influence public health information behavior.

Insights into user preferences highlight some important issues related to eosinophilic diseases, particularly in the area of diagnosis. Conversely, public health efforts should focus on simplified and accessible materials for patients in the early stages, containing credible knowledge about symptoms and evaluations to support efficient and correct diagnosis. Searching and geographically examining keywords can enable targeted public health campaigns in unconscious areas, which can shorten the diagnostic delay and lead to earlier detection and better outcomes. Seasonal peaks in search volume, particularly during the winter months, may reflect worsening of respiratory symptoms due to the colder weather [41]. Due to the exacerbation of eosinophilic diseases, including HES, during this period, people feel the need for more information [41]. The peaks can also be explained by increased public health campaigns or media attention, as respiratory problems tend to receive more attention during the flu season [42].

Regions with lower engagement, such as Saxony-Anhalt and Bremen, may benefit from targeted outreach strategies to increase awareness and education about eosinophilic disorders. Health campaigns in these areas could focus on improving access to information, addressing gaps in public knowledge, and raising awareness about available specialized care centers [43-46]. Additionally, digital platforms, including social media and search engines, can be leveraged to disseminate accurate and timely information, directly reaching individuals in these regions who may not have access to traditional sources of health education. Such approaches could help reduce diagnostic delays by guiding individuals to seek appropriate care sooner and more effectively [43].

To validate the findings, data from social media and internet-based news were examined. The trends, especially the peaks in January 2023 and October 2022, align with search volume spikes. However, social media data may reflect specific user groups rather than the broader population, and news data can be influenced by external factors such as public health campaigns. While these sources provide useful insights, they should be interpreted cautiously as they may not fully capture the overall public interest in eosinophilic disorders.

Comparison With Literature

The findings of our study are consistent with previous research on rare diseases, which highlights the significant challenges faced by patients in obtaining a timely and accurate diagnosis. Hypereosinophilic disorders present with complex clinical features that can lead to diagnostic delays and misdiagnoses, similar to other rare conditions. The 2013 report on the impact of rare diseases shows that patients with rare diseases often have to undergo long diagnostic pathways. In the United States, it takes an average of 7.6 years, and in the United Kingdom, 5.6 years before a correct diagnosis is made [44]. During this period, patients typically consult up to 8 physicians and receive 2-3 misdiagnoses, with 82% of social media comments on HES reporting diagnostic delays, highlighting the complexity of diagnosing rare eosinophil-driven disorders [45].

In our study, the diagnosis-related subcategory was the most frequently searched, reflecting the public's struggle to find accurate information and the challenges associated with diagnosing hypereosinophilic disorders [46,47]. This pattern of information-seeking behavior suggests a significant unmet need for awareness and educational resources, both for the public and health care professionals [48].

This finding aligns with previous research on atopic dermatitis and pollen allergies, which also indicated that online search data could reveal significant gaps in public knowledge and help identify areas requiring targeted health education [26,29,49-51].

Strengths and Limitations

A key strength of this study is its use of Google Ads Keyword Planner, providing real-time search data to assess public interest in eosinophilic disorders. This approach demonstrates the potential of infodemiology for rare disease research, offering insights into awareness, informational needs, and regional variations, which traditional data sources often lack. Compared with studies such as Pauer et al [52], which used search queries for rare disease epidemiology, our study focuses specifically on eosinophilic disorders, adding nuance to public engagement analysis [53,54]. Additionally, unlike Pauer et al [52] and Tozzi et al [55], which examined information quality and user demographics, we provide real-time trends in public interest, enhancing the understanding of disease awareness.

Several limitations should be considered when interpreting these findings. Google Ads Keyword Planner, while effective for data collection, is primarily a marketing tool and may introduce biases or limitations in data accuracy for research purposes [56,57]. The high search volume for misspelled terms such as "eosophile" may have skewed the results and points to gaps in public education that were not fully explored in this study. Future research could investigate the reasons behind common misspellings and their impact on information retrieval and understanding. Furthermore, the generalizability of the results may be limited by demographic and access biases. Younger people are generally more tech-savvy and therefore more likely than older cohorts to search for health information on Google, skewing the search data toward their demographic group. This study did not account for differences in internet use by age, socioeconomic status, and region, and the results may not generalize to different segments of the population [58]. The final limitation concerns the temporal relevance of the data, which extend to December 2023 but may not account for newer trends or developments, such as newer treatment options or educational campaigns, that could influence interest and search behavior outside the time frame of this study.

Conclusion

The findings of this study provide valuable insights into public interest and information-seeking behaviors related to hypereosinophilic disorders in Germany. The data suggest that there is a growing awareness and concern about these rare conditions, as evidenced by the increasing search volumes over time. The pronounced regional differences highlight the need for localized health education and resource allocation to address potential disparities in awareness and access to information.

Our results emphasize the urgent need for faster, more accurate diagnostic pathways and enhanced awareness among health care professionals to improve the management and outcomes for patients with rare diseases such as HES and EGPA. The study underscores the potential of using Google search trends as a tool for public health surveillance, particularly for rare and underrecognized conditions such as hypereosinophilic disorders. Future research should aim to integrate demographic data and explore the impact of public health campaigns and health care access on search behaviors. Additionally, efforts should be made to improve public understanding of these disorders through accurate and accessible information, potentially leveraging the very platforms where information-seeking is occurring. Addressing these knowledge gaps could lead to better patient outcomes through earlier diagnosis and more informed health decision-making.

Acknowledgments

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Data Availability

The datasets generated or analyzed during this study are available from the corresponding author on reasonable request.

Authors' Contributions

MH was responsible for conceptualization, methodology, investigation, formal analysis, and writing the original draft. SS contributed to conceptualization, methodology, and writing, as well as review and editing. AZ also contributed to conceptualization, methodology, and writing, as well as review and editing.

Conflicts of Interest

MH once received a personal honorarium from GSK, AZ received personal honoraria from GSK, and SS has no conflict of interest.

Multimedia Appendix 1

A correlation matrix of search volume data for various keywords related to eosinophilic disorders across 27 cities in Germany. This matrix highlights the relationships between different terms such as "eosinophilia," "Churg-Strauss syndrome," "HES," and related treatments and conditions. The data reflect regional variations with notable differences in search volume across cities. These correlations provide insights into public interest in specific aspects of eosinophilic disorders and help identify patterns in search behaviors linked to geographic location.
[DOCX File (Microsoft Word File), 2057 KB-Multimedia Appendix 1]

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Abbreviations

CEL-NOS: chronic eosinophilic leukemia-not otherwise specified
EGPA: eosinophilic granulomatosis with polyangiitis
HES: hypereosinophilic syndrome
I-HES: idiopathic hypereosinophilic syndrome
L-HES: lymphocytic hypereosinophilic syndrome
M-HES: myeloproliferative hypereosinophilic syndrome

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4. Appendix

4.1 Paper V

Review

Transforming Health Care Through Chatbots for Medical History-Taking and Future Directions: Comprehensive Systematic Review

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Abstract

Background: The integration of artificial intelligence and chatbot technology in health care has attracted significant attention due to its potential to improve patient care and streamline history-taking. As artificial intelligence–driven conversational agents, chatbots offer the opportunity to revolutionize history-taking, necessitating a comprehensive examination of their impact on medical practice.

Objective: This systematic review aims to assess the role, effectiveness, usability, and patient acceptance of chatbots in medical history–taking. It also examines potential challenges and future opportunities for integration into clinical practice.

Methods: A systematic search included PubMed, Embase, MEDLINE (via Ovid), CENTRAL, Scopus, and Open Science and covered studies through July 2024. The inclusion and exclusion criteria for the studies reviewed were based on the PICOS (participants, interventions, comparators, outcomes, and study design) framework. The population included individuals using health care chatbots for medical history–taking. Interventions focused on chatbots designed to facilitate medical history–taking. The outcomes of interest were the feasibility, acceptance, and usability of chatbot-based medical history–taking. Studies not reporting on these outcomes were excluded. All study designs except conference papers were eligible for inclusion. Only English-language studies were considered. There were no specific restrictions on study duration. Key search terms included “chatbot*,” “conversational agent*,” “virtual assistant,” “artificial intelligence chatbot,” “medical history,” and “history-taking.” The quality of observational studies was classified using the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) criteria (eg, sample size, design, data collection, and follow-up). The RoB 2 (Risk of Bias) tool assessed areas and the levels of bias in randomized controlled trials (RCTs).

Results: The review included 15 observational studies and 3 RCTs and synthesized evidence from different medical fields and populations. Chatbots systematically collect information through targeted queries and data retrieval, improving patient engagement and satisfaction. The results show that chatbots have great potential for history-taking and that the efficiency and accessibility of the health care system can be improved by 24/7 automated data collection. Bias assessments revealed that of the 15 observational studies, 5 (33%) studies were of high quality, 5 (33%) studies were of moderate quality, and 5 (33%) studies were of low quality. Of the RCTs, 2 had a low risk of bias, while 1 had a high risk.

Conclusions: This systematic review provides critical insights into the potential benefits and challenges of using chatbots for medical history–taking. The included studies showed that chatbots can increase patient engagement, streamline data collection, and improve health care decision-making. For effective integration into clinical practice, it is crucial to design user-friendly interfaces, ensure robust data security, and maintain empathetic patient-physician interactions. Future research should focus on refining chatbot algorithms, improving their emotional intelligence, and extending their application to different health care settings to realize their full potential in modern medicine.

Trial Registration: PROSPERO CRD42023410312; www.crd.york.ac.uk/prospero

(JMIR Med Inform 2024;12:e56628) doi: 10.2196/56628

KEYWORDS

medical history-taking; chatbots; artificial intelligence; natural language processing; health care data collection; patient engagement; clinical decision-making; usability; acceptability; systematic review; diagnostic accuracy; patient-doctor communication; cybersecurity; machine learning; conversational agents; health informatics

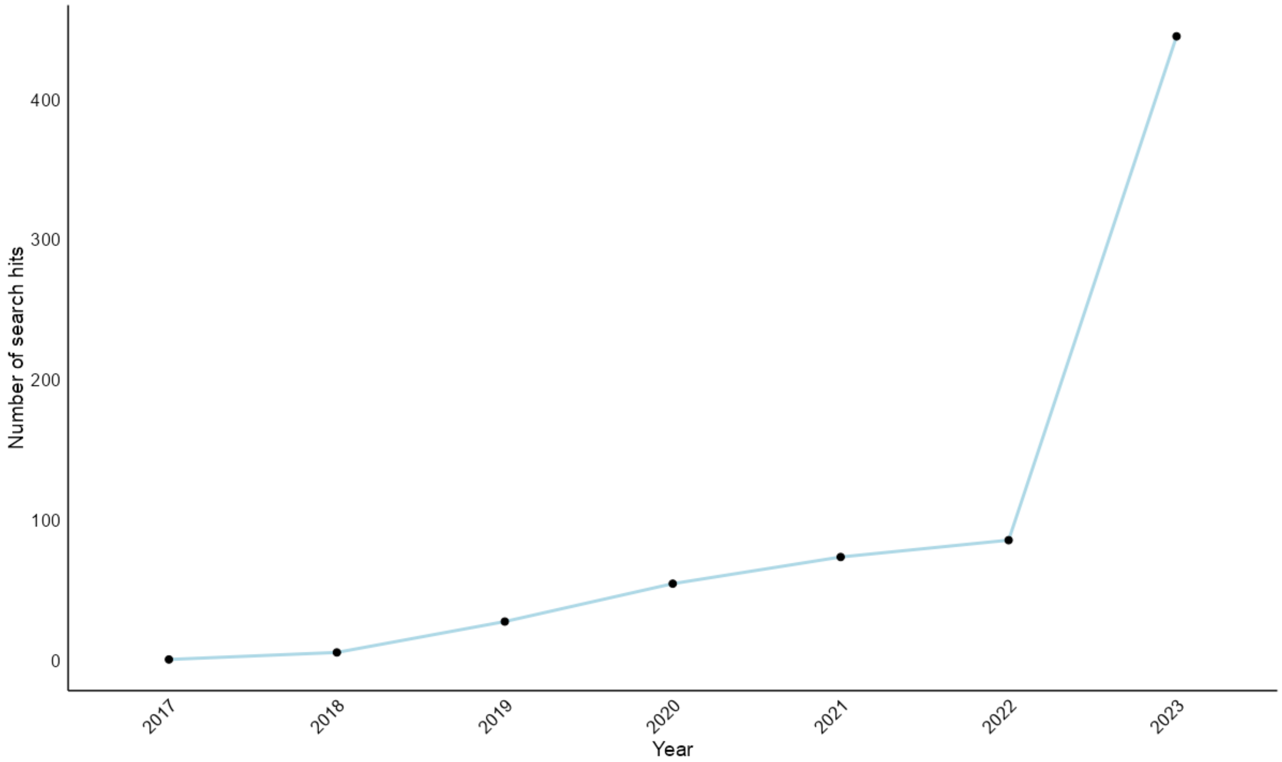
Introduction

Taking a patient's medical history is of central importance in the health care sector. Collecting comprehensive data is essential for accurate diagnosis and customized treatment [1]. Traditionally, clinicians have relied on interviews or questionnaires to gather this important information, but these methods can lack efficiency and accuracy, potentially leading to incomplete records and low patient engagement [2]. New technologies have brought about innovative solutions to streamline documentation, such as chatbots, with their ability to digitally transform data collection [3]. Chatbots can use artificial intelligence (AI) and natural language processing (NLP) to simulate conversations and minimize the limitations of paper-based processes [4-6]. The integration of chatbots promises significant improvements in care by enabling accurate, streamlined documentation that supports personalized, evidence-based clinical decision-making and greater patient engagement [7,8]. While chatbots are widely used in other areas, such as entertainment, customer service [9], security systems, and emergency communications [10-12], there is a lack of thorough research evaluating their effectiveness, usability, and acceptability of chatbots specifically for health care data collection. Research has focused on a narrow area without contextualizing the broader implications. To date, few people have had access to sophisticated AI due to its cost and complexity. However, new publicly available models, such as ChatGPT, are making these capabilities accessible to a wide audience by analyzing large amounts of literature and data in seconds to make time-critical decisions in a more data-driven and accurate way [13-17]. For interactions in the health care sector, specific and individual patient profiles can be addressed in order to improve documentation and the associated health outcomes. In addition, continued adoption will ensure that counseling by health care professionals remains widely accessible, especially in underserved communities [18]. In addition, their ability to work continuously and remotely can improve health care by ensuring that expert-level advice is always available, improving access to quality care, especially in underserved areas [18,19]. However, these benefits must be balanced by robust measures to ensure that the use of AI in health care improves, rather than undermines, patient care and trust [20].

Despite the promise of chatbots, important considerations are taken into account, particularly in health care. Cybersecurity is paramount, as chatbots handle sensitive medical information that must be protected from unauthorized access or data breaches [21,22]. Furthermore, despite the remarkable capabilities of chatbots in effectively processing and generating responses through predefined algorithms, they often lack the empathetic understanding and emotional intelligence inherent in human interactions [23]. This limitation can affect relationship-building and patient trust, especially during sensitive medical conversations [20].

Recent data highlighted the growing interest in the interplay between chatbots and medicine. An analysis of studies from the first study in 2017 to 2024 with the search query "chatbot*" AND "medicine" shows a significant increase, especially in 2022, with the trend rising from a single study in 2017 to 445 in 2023 (Figure 1).

Figure 1. Number of studies over recent years: “chatbot*” AND “medicine.” This chart shows the increasing trend in publications on chatbots in medicine from 2017 to 2023. In 2022, there was an exponential increase in published studies, indicating a growing research interest and progress in chatbots in medicine.



Chatbots rely on advanced algorithms and AI-supported NLP for their technical function. These techniques enable chatbots to examine user input, provide applicable data in the form of feedback, and modify their interactions depending on context and user behavior, which can be refined through machine learning approaches, including information-driven learning and pattern recognition [24-26].

Considering the potential benefits and problems associated with chatbots, a thorough investigation is essential to assess their impact on the process of medical history–taking. While existing studies have examined the practicality and acceptability of chatbots in specific medical areas, such as psychological well-being or genetic counseling, a systematic literature review is needed for a complete understanding of chatbot-based history-taking [27-29].

The primary objective of this systematic review is to provide a comprehensive assessment of the role, effectiveness, usability, and patient acceptance of chatbots in medical history–taking. This systematic review also aims to explore the impact and future directions of integrating chatbots into clinical settings by assessing data accuracy, level of patient interaction, health care provider efficiency, and patient outcomes. Chatbots could transform the process of taking medical histories by supporting the accurate capture of patient information. In addition, this has the potential to increase productivity and improve the quality and delivery of health care services.

Methods

Overview

The systematic analysis was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for reporting systematic reviews to ensure transparency [30]. The protocol was registered under registration number CRD42023410312 in the PROSPERO database of the National Institute for Health Research [31].

Eligibility Criteria

Eligibility criteria for the studies were based on the PICOS (participants, interventions, comparators, outcomes, study design) framework for assessing participant demographics, types of interventions assessed, study designs, and outcome of interest [32]. We aimed to identify research investigating chatbots to facilitate medical history–taking to support physicians in diagnosis and treatment planning. The scope was limited to chatbots that facilitate patient disclosure of personal health information to improve accuracy and support clinical decision-making. In contrast, chatbots designed exclusively as “symptom-checkers,” such as stand-alone apps providing rapid assessments and potential diagnoses, were excluded. This exclusion was made to focus on tools that facilitate comprehensive medical history–taking rather than immediate symptom-based advice. There were no limitations on the modality of chatbot input and output. The comparators were not subjected to any specific restrictions. The outcomes of interest included the feasibility, acceptability, and efficacy of chatbot-based history-taking interventions. There were no restrictions on study design, except for conference papers, which were excluded to ensure the inclusion of studies with rigorous peer review and substantial data reporting. The review was limited to English-language studies because resources were limited.

Information Sources

PubMed, CENTRAL, Embase, MEDLINE (through Ovid), Scopus, and Open Science were searched to identify relevant studies. In addition, reference lists of relevant studies were screened manually.

Search Strategy

For each database, we developed a search strategy that included keywords, subject headings, mesh terms (in PubMed), filters, and restrictions to find relevant studies. The search terms focused on chatbots, anamnesis, history-taking, and related concepts: (“chatbot*” OR “conversational agent*” OR “chatterbot*” OR “virtual assistant” OR “intelligent virtual agent” OR “artificial intelligence chatbot” OR “AI chatbot” OR “conversational AI” OR “dialogue system”) AND (“anamnesis” OR “medical history” OR “history-taking” OR “medical interview” OR “patient interview” OR “medical questionnaire” OR “patient questionnaire”). The last search was done in July 2024 (Multimedia Appendix 1). Additionally, a reference list search was conducted.

Selection Process

The selection process was done by 2 authors (MH and SS) independently screening the titles and abstracts of the identified studies based on the predetermined eligibility criteria. Potentially relevant studies were retrieved in full text and further assessed for eligibility. The full-text assessment was also performed independently (MH and SS). Any disagreements between the 2 authors were resolved through discussion, focusing on the eligibility criteria and study relevance. If consensus could not be reached, the involvement of a third author (AZ) was sought when necessary.

Data Collection Process

Data from the selected studies were extracted independently (MH and SS) using a data extraction form based on the PICO criteria (STROBE [Strengthening the Reporting of Observational Studies in Epidemiology]) [32,33]. The extracted data included information such as the first author, number of authors, country, year, title of the scientific journal, topics and type of journal, impact factor, and main results focused on history-taking (anamnesis). Additional data collected encompassed study design, setting, sample size, type of participants, female percentage, mean age (range), and results. Outcomes extracted focused on key aspects such as feasibility, acceptability, and efficacy. When full-text access was unavailable, the corresponding author was contacted by email. Data were visualized using the R-package for creating alluvial diagrams [34]. Any discrepancies in data extraction were resolved through a discussion between the 2 authors (MH and SS).

Quality Assessment

The methodological quality of the included observational studies was assessed using the STROBE criteria [33]. Each study was evaluated based on the fulfillment of the STROBE criteria. The studies were categorized into 3 categories: category A, if more than 80% of the STROBE criteria were fulfilled; category B, if 50%-80% were met; and category C if less than 50% of the criteria were fulfilled [35]. For example, category A studies provided comprehensive details on study objectives, participant selection, and statistical analysis. Category B had adequate but incomplete information. Category C studies frequently lacked critical details such as clear definitions of eligibility criteria or thorough data collection methods.

In addition, the RCTs included in this review were evaluated for risk of bias using the Risk of Bias tool and the robvis R-package [36,37]. The RoB 2 tool assesses various domains of bias, including randomization, allocation concealment, blinding, incomplete outcome data, selective reporting, and other potential sources of bias. The overall risk of bias score was determined for each study based on the number of criteria for high risk of bias met. Studies are considered to have a low risk of bias if no domains are rated as high risk and most domains are rated as low risk. Studies with some concerns in one or more domains but no high-risk ratings are considered to have some concerns. If any domain is rated as high risk, the study is considered to have a high risk of bias.

Software and Tools

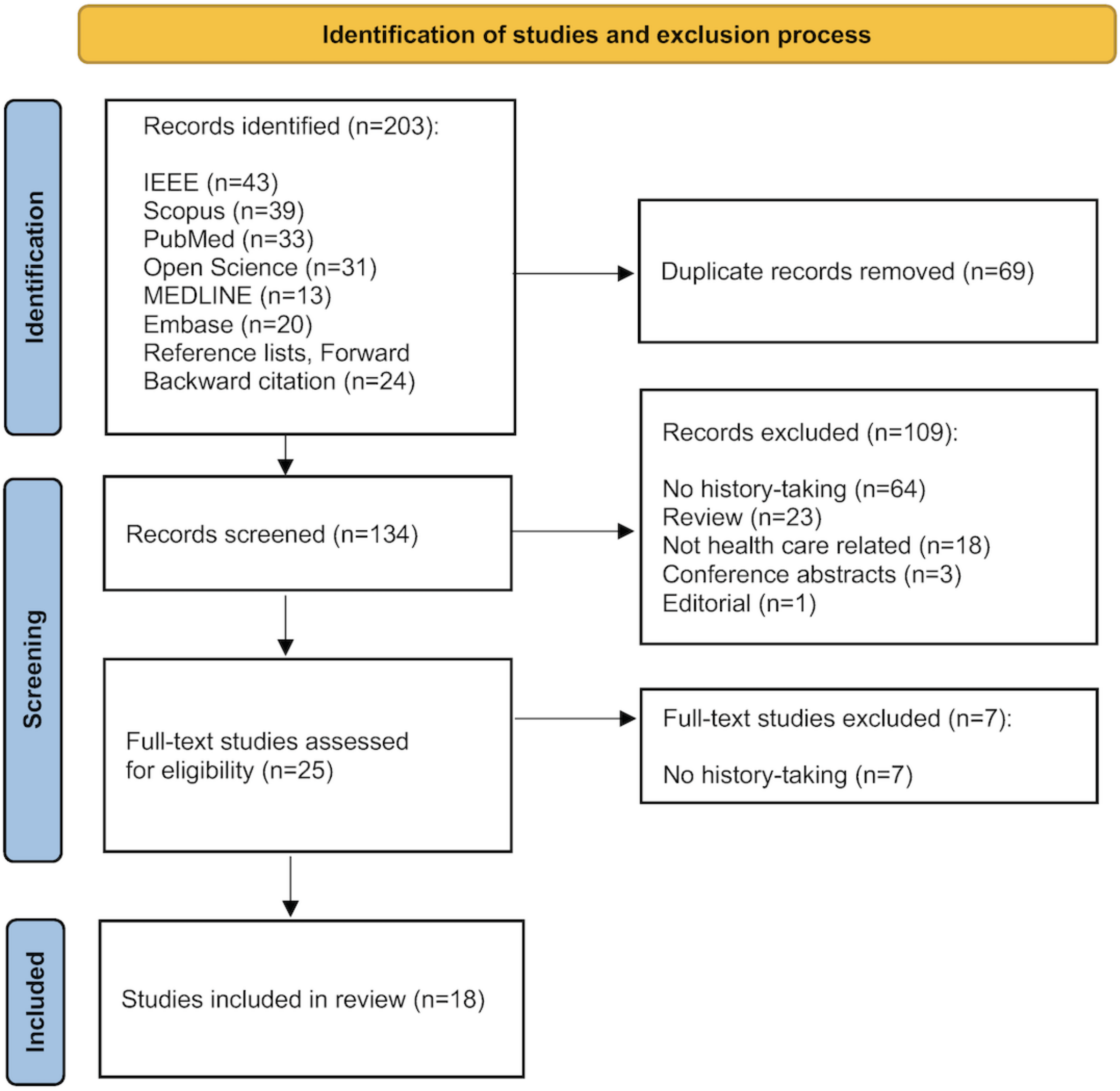
Data were managed and analyzed using R (version 4.2.1; The R Foundation). The ggplot2 package [38] was used for data visualization and the robvis R-package was used for risk of bias charts [37]. The alluvial R package [34] was used to create alluvial diagrams.

Results

Study Selection

The initial literature search yielded 203 records. After removing 69 duplicate studies, a total of 134 unique records were screened based on titles and abstracts. Of these, 109 studies did not meet the eligibility criteria and were excluded. Subsequently, 25 full-text studies were screened, resulting in 18 studies being included in the review (Figure 2).

Figure 2. Flowchart of the study search and inclusion. This flowchart details the systematic process of selecting studies for the review, starting from 203 records and narrowing down to 18 studies after removing duplicates and applying eligibility criteria. IEEE: Institute of Electrical and Electronic Engineers.



Study Characteristics

The studies investigated the use of chatbots for history-taking across diverse patient populations and sample sizes (range: n=5-61,070) and were mostly published in scientific health technology journals with varying impact factors (mean 4.52, SD 4.49; range: 0.14-14.71; Table 1). The studies used different research designs, including 9 cross-sectional studies, 3 case-control studies, 2 observational studies, and 3 RCTs (Multimedia Appendix 1 and Tables 1-3).

Table 1. General characteristics of the included studies. This table summarizes the number of authors, countries, and journal topics of the studies, showing most research from Germany and the United States, and a focus on Health Informatics and Technology.

	Count, n (%)
Numbers of authors	
1-3	4 (22)
4-6	8 (44)
>6	6 (33)
Countries	
Germany	6 (33)
United States	6 (33)
Switzerland	3 (17)
Australia	2 (11)
New Zealand	1 (6)
Scientific journals	
Topics of scientific journals	
Health Informatics and Technology	12 (67)
Medical Imaging and Radiology	2 (11)
Genetics and Genetic Counseling	2 (11)
Surgical Procedures and Techniques	1 (6)
Mental Health and Psychology	1 (6)

Table 2. Study characteristics. This table details study characteristics, including author, year, design, sample size, participant type, and key findings, highlighting diverse participant demographics and study outcomes.

Reference		Participants				Methods and result	
Authors (year)	Study design	n	Type of participants	Female (%)	Mean age (years)	Type of measurement	Relevant results
Denecke et al (2018) [39]	Cross-sectional study	22	Music therapy patients	41	39 (range 19-73)	Usability test of the tool and corresponding questionnaire	CUI[a]-based self-anamnesis app well-received, potential for collecting anamnesis data.
Denecke et al (2022) [40]	Cross-sectional study	5	Radiology patients	40	39.2 (range 17-73)	System usability scale	Digital medical interview assistant with good usability.
Faqar-Uz-Zaman et al (2022) [41]	RCT[b]	450	Patients with abdominal pain in ER[c]	52.2	44 (range 18-97)	Accuracy of diagnosis by ER doctor and Ada app according to the final diagnosis	Classic patient-physician interaction superior to AI[d]-based tool, but AI benefits diagnostic efficacy.
Frick et al (2021) [42]	Cross-sectional study	148	German participants	53	33.32 (SD 12.59)	Scales for disclosure and concealment of medical information	Patients prefer disclosing to physicians over chatbots. No significant difference in concealment.
Gashi et al (2021) [43]	Cross-sectional study	N/A[e]	N/A	N/A	N/A	N/A	AnCha chatbot improves patient-doctor communication, enhances diagnostic process.
Ghosh et al (2018) [44]	Case-control study	30 scenarios	Not specified	N/A	N/A	True positives and false positives, precision	Medical chatbot helps with automated patient pre-assessment.
Heald et al (2021) [27]	Feasibility study	506	Various types of care	58	56.6 (SD 12.5)	Colon cancer risk assessment tool	Chatbot feasible for increasing genetic screening in at-risk individuals.
Hennemann et al (2022) [45]	Observational study	49	Adult patients from an outpatient psychotherapy clinic	61	33.41 (SD 12.79)	Interviews, questionnaires, diagnostic software	Chatbot shows moderate to good accuracy for condition suggestions.
Hong et al (2022) [46]	Cross-sectional study	20	Primary care patients	60	50	Web-based survey	Patients believe chatbot helps clinicians better understand their health.
Ireland et al (2021) [28]	Cross-sectional study	83	Adults who had whole exome sequencing for genetic condition diagnosis	53	range 23.2-80.4	Transcript analysis	Chatbot enhances genetic counseling by providing genomic information.
Jungmann et al (2019) [47]	Case-control study	6	Psychotherapists, psychology students, and laypersons	50	40 (therapists) 22 (students)	Case vignettes, health app comparison	Chatbot shows moderate diagnostic agreement, improvement needed for childhood disorders.
Nazareth et al (2021) [48]	Retrospective, observational study	61,070	Women's health	96	N/A	Genetic testing results	Chatbot helps identify patients at high risk for hereditary cancer syndromes.
Ni et al (2017) [49]	Cross-sectional study or proof-of-concept	11	Patients with chest pain, respiratory infections, headaches, and dizziness	N/A	N/A	Question accuracy, prediction accuracy	Chatbot generates medical reports with varying accuracy based on disease category.

Reference		Participants				Methods and result	
Authors (year)	Study design	n	Type of participants	Female (%)	Mean age (years)	Type of measurement	Relevant results
Ponathil et al (2020) [50]	Cross-sectional study	50	Adults	50	N/A	NASA Task Load Index workload instrument IBM Usability Questionnaire Technology Acceptance Model Questionnaire	Chatbot interface saves time, preferred for collecting family health history.
Reis et al (2020) [51]	Case-control study	16	Physicians	35	35.51	N/A	Failure of cognitive agent highlights need for managing resistance and transparency.
Schneider et al (2023) [52]	RCT	30	Hymenoptera venom allergic patients	N/A	38.93 (SD 12.56)	Standardized questionnaire	Chatbot-supported anamnesis saves time, potential for allergology assessments.
Wang et al (2015) [29]	RCT, hospital	70	Majority of patients from underserved populations (low-income families, elders, people with disabilities, and immigrants)	60	Majority in age group 45-54	Interview, questions	Technological support for documenting family history risks is accepted and feasible.
Welch et al (2020) [53]	Cross-sectional study	3204	General population	100	49.4 (SD 7.1)	Standardized questionnaire	Chatbot engages users, potential for gathering family health history at population level.

[a] CUI: conversational user interface.

[b] RCT: randomized controlled trial.

[c] ER: emergency room.

[d] AI: artificial intelligence.

[e] Not applicable.

Table 3. Chatbot characteristics. This table outlines the chatbots used in the studies, including their name, goal, modality, techniques, outcomes, user preferences, and challenges, showcasing varied applications and technological approaches in health care. Table format based on Schachner et al [54].

Authors (year)	Name	Goal	Modality	Techniques	Main outcomes	User preference	Challenges
Denecke et al (2018) [39]	Ana	Collect medical history for music therapy	Mobile app: Text input	AIML[a], rule-based	Comprehensive data collection, usability	Engaging, intuitive	Integration, diverse interactions, data completeness
Denecke et al (2022) [40]	Not specified	Improve radiological diagnostics	Telegram CUI[b]	RiveScript (rule-based)	Enhanced knowledgeability, diagnostic quality	User-friendly	Clinical workflow integration, data security
Faqar-Uz-Zaman et al (2022) [41]	Ada	Evaluate diagnostic accuracy in ER[c]	iPad app	AI[d] questionnaire, ML[e]	Increased diagnostic accuracy	Not specified	Physician integration, diagnostic variability
Frick et al (2021) [42]	Not specified	Elicit truthful medical disclosure	Digital survey	Common CA[f] technologies	Disclosure versus concealment	Prefer physicians	Information accuracy, privacy
Gashi et al (2021) [43]	AnCha	Collect previsit medical history	IBM Watson, web-based	Rule-based tree	Efficient data collection	Reduces previsit anxiety	Clinical integration, data security
Ghosh et al (2018) [44]	Quro	User symptom check, personalized assessments	Web interface	NLP[g], ML	Precision in condition prediction	High engagement	Data complexity, accurate predictions
Heald et al (2021) [27]	Not specified	Screen for heritable cancer syndromes	Web-based, text-based	AI conversation, NLP	Efficient risk assessment, facilitated testing	High engagement, completion rates	Workflow integration, genetic risk understanding
Hennemann et al (2022) [45]	Ada	Diagnose mental disorders	App-based symptom checker	AI analysis, NLP	Moderate diagnostic accuracy	Mixed preferences	Diagnostic performance, user input dependency
Hong et al (2022) [46]	Genie	Collect detailed medical histories	Web-based, AI speech-to-text	AI, NLP	Improved history collection	Helpful for PCPs[h]	Ease of use, AI use concerns
Ireland et al (2021) [28]	Edna	Support genomic findings decision-making	Mobile, tablet, PC	NLP, Sentiment Analysis	Enhanced patient agency, informed decisions	Ease of access, supports consent	Empathy, complex interactions, data privacy
Jungmann et al (2019) [47]	Ada	Diagnose mental disorders	Mobile app	AI symptom analysis	Moderate diagnostic agreement	Not specified	Accuracy for complex cases
Nazareth et al (2021) [48]	Gia	Hereditary cancer risk triage	Web-based, mobile	NLP	Automated risk triage, educational interactions	High engagement	Workflow integration, privacy, diverse needs
Ni et al (2017) [49]	Mandy	Automate patient intake	Mobile app	NLP, data-driven analysis	Reduced staff workload, privacy maintenance	Improves physician efficiency	Full clinical integration, privacy, diverse interactions
Ponathil et al (2020) [50]	VCA	Collect family health history	Web-based chat	Not specified	Higher satisfaction, lower workload	Preferred by most users	Multiple clicks, extensive interaction
Reis et al (2020) [51]	Cognitive Agent	Automate anamnesis-diagnosis-treatment	Voice-based AI chatbot	ML, NLP, speech recognition	Reduced documentation time	Reduces nonbillable activities	Physician resistance, legal concerns, oversimplification
Schneider et al (2023) [52]	Not specified	Standardize allergy history-taking	HTML-based, digital	HTML, Java scripting	Time-efficient, accurate history-taking	High satisfaction	Question clarity, specificity
Wang et al (2015) [29]	VICKY	Collect family health histories	Touch-screen tablet	Speech recognition, decision trees	High satisfaction, effective identification	Easy to use, recommended	Data entry issues, complex questions
Welch et al (2020) [53]	It Runs In My Family	Assess hereditary cancer risk	Web-based chatbot	NLP	High engagement, thorough assessments	Prefer chatbot to web forms	Data accuracy, interface design, demographic reach

[a] AIML: artificial intelligence markup language.

[b] CUI: conversational user interface.

[c] ER: emergency room.

[d] AI: artificial intelligence.

[e] ML: machine learning.

[f] CA: conversational agent.

[g] NLP: natural language processing.

[h] PCP: primary care physician.

The alluvial diagram (Figure 3 [27,29,39-53]) shows an overview of the literature over time, indicating the year, the country of origin, and the medical area of focus for each study. The included studies were published from 2015 to 2023. Most of the studies were published in 2020 and 2022. The included studies (Figures 3 [27,29,39-53] and 4) were conducted in Switzerland [39,40,43], Germany [41,42,45,47,51,52], the United States [27,29,46,48,50,53], Australia [28,44], and New Zealand [49]. The studies cover a diverse range of medical areas: general medicine [42-44,49,51] genetics [28,29,48,50] cancer research [27,53], family medicine [46], mental health [45,47], radiology [40], surgery [41], allergy [52], and music therapy [39].

Figure 3. Alluvial diagram of the publication date, country, and area of studies. The alluvial diagram illustrates the distribution of studies by year, country, and medical area from 2015 to 2023, highlighting increased publications in 2020 and 2022, with contributions from Germany, the United States, and Switzerland across various medical fields.

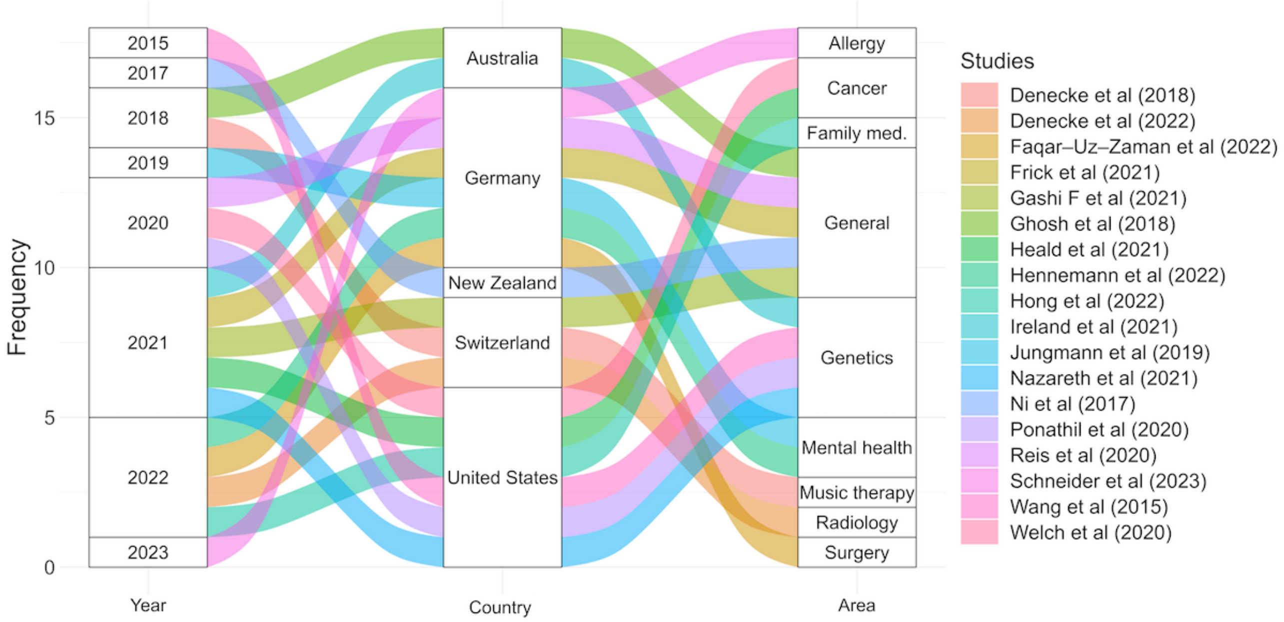
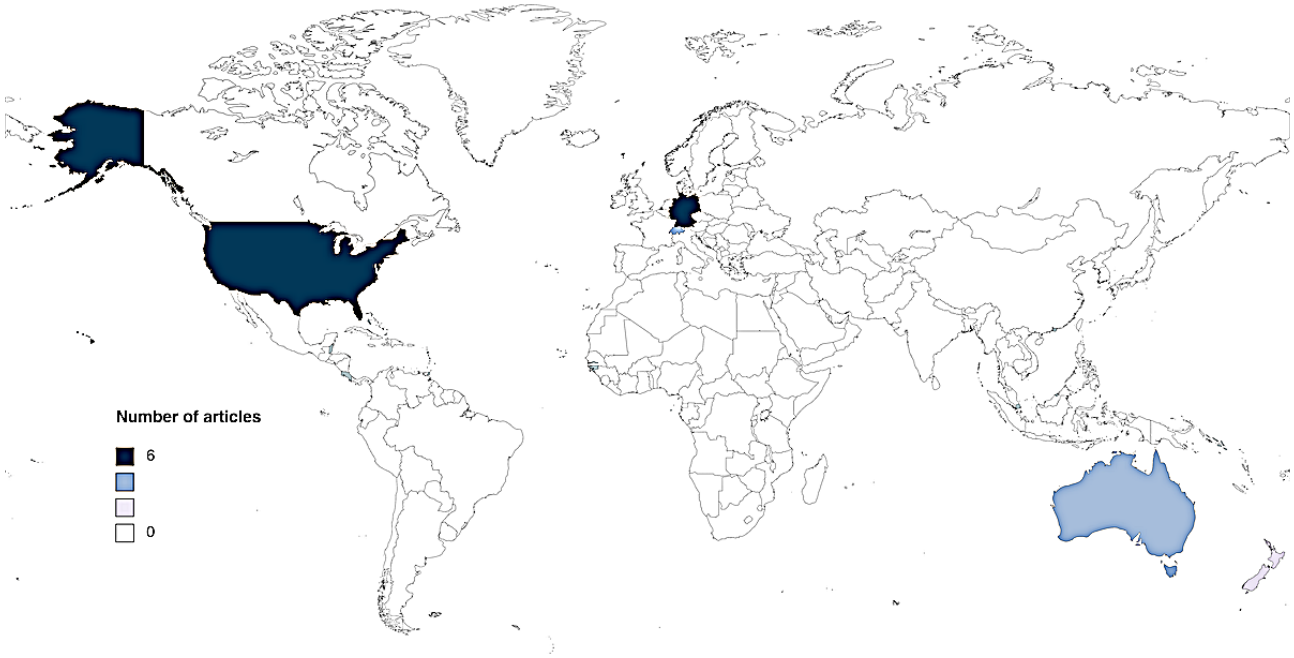


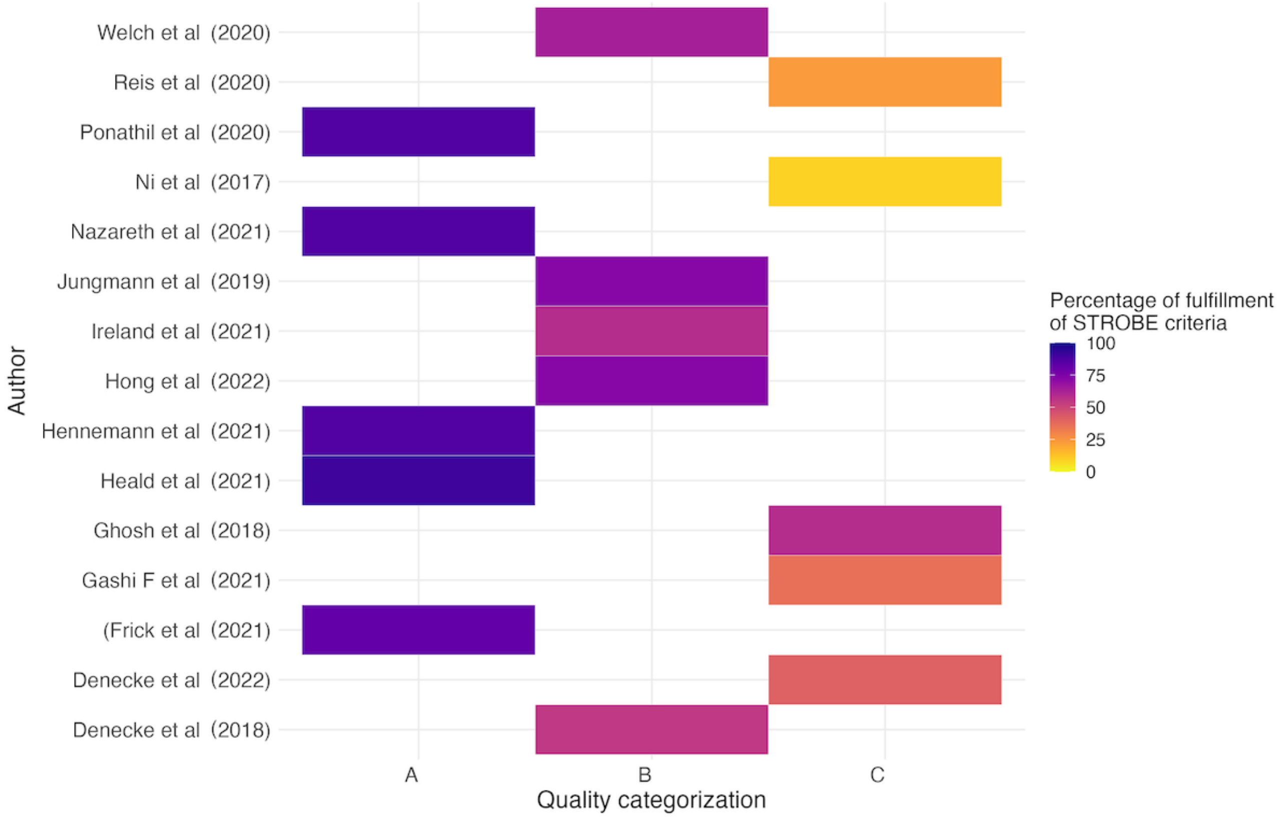
Figure 4. World map showing the number of studies published in each country. This map shows the geographical distribution of the studies, with most research originating from Germany and the United States. Created with MapChart [55].



Quality Appraisal of the Included Studies

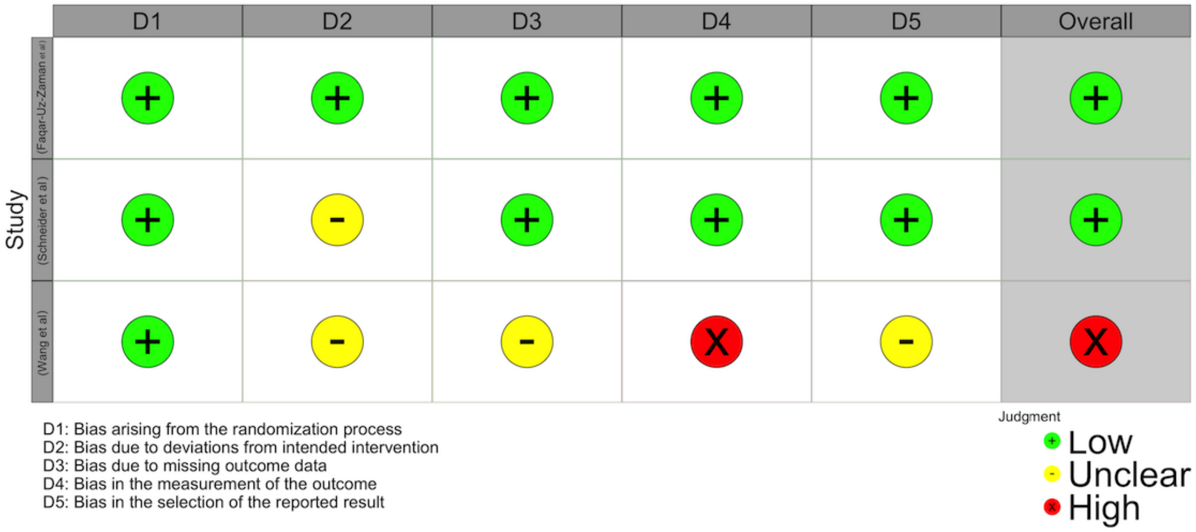
Among the 16 observational studies, 6 (38%) studies were classified as category A [27,42,45,48,50], indicating high methodological quality with more than 80% of the STROBE criteria fulfilled (Multimedia Appendix 1). A total of 5 (31%) studies were classified as category B [28,39,46,47,53], meeting 50%-80% of the STROBE criteria, and 5 (31%) studies were classified as category C [40,43,44,49,51], meeting less than 50% of the STROBE criteria (Figure 5 [27,28,39,40,42-51,53]). The lack of adherence to STROBE criteria in observational studies can have a significant impact on the quality. Missing elements, such as clear definitions of eligibility criteria or participants or detailed methods, lead to biases that reduce validity and reliability. For example, the study of Denecke et al [40] showed a high risk of selection bias due to a small, nonrepresentative sample and lack of eligibility criteria, limiting the generalizability of their findings. Gashi et al [43] faced biases from the absence of a control group and unclear eligibility criteria. This could impact the validity of the effectiveness results. Ghosh et al [44] showed high bias from simulated scenarios without real patient interactions. This could lead to overestimated accuracy and applicability in real-world settings.

Figure 5. Fulfillment of STROBE criteria and categorization. This bar chart categorizes observational studies by their adherence to STROBE criteria, showing 37.5% of high-quality (category A), and an even split between moderate (category B) and lower quality (category C). STROBE: Strengthening the Reporting of Observational Studies in Epidemiology.



The studies by Schneider et al [52] and Faqar-Uz-Zaman et al [41] showed a low risk of bias according to the RoB tool, with detailed methodology and statistical analysis. In contrast, the study by Wang et al [29] showed a risk of bias due to the absence of intention-to-treat analysis and participants being aware of the intervention (Multimedia Appendix 1 and Figure 6), which could skew results by excluding noncompleters and altering participant behavior.

Figure 6. Risk of bias domains (RoB-tool) for randomized controlled trials.



Summary of Statistical Analyses

The studies included in this systematic review used a variety of statistical methods. Descriptive statistics summarized demographics and usability ratings. Comparative analyses used 2-tailed *t* tests and chi-square tests to compare diagnostic accuracy and user engagement. κ statistics measured agreement between chatbot and expert diagnoses. Precision and accuracy metrics were assessed using precision, recall, and F_1-scores. Nonparametric tests, such as the Mann-Whitney *U* test showed significant reductions in anamnesis duration. CIs and *P* values were reported where relevant to clarify the strength of the evidence.

Usability and User Experience of Chatbots

Five studies focused on the usability and user experience of chatbots in history-taking (Tables 2 and 3). Denecke et al [39,40] found that chatbots were well-received by participants and showed potential for history-taking. Usability scores were high, between 90 and 100 (average 96). Ponathil et al [50] found that using a voice-controlled assistant interface for taking family health history significantly reduced history-taking duration. Ghosh et al [44] implemented a medical chatbot that assists with automated patient preassessment through symptom analysis, demonstrating the possibility of avoiding form-based data entry. The chatbot correctly identified at least one of the top three conditions in 83% (n=25) of cases and two out of three conditions in 67% (n=20) of cases. Welch et al [53] found high engagement and interest in chatbots, suggesting the potential for gathering family health history information at the population level in the United States. Of the over 14,000 who participated in the assessment of the study, 54.4% (n=7616) of users went beyond the consent step, and 22.7% (n=3178) of users completed the full assessment.

Chatbots and Patient-Doctor Communication

One study highlighted the potential of chatbots to improve patient-doctor communication. Gashi et al [43] reported that using a chatbot could reduce patient nervousness, allow patients to respond more thoughtfully, and give physicians a more comprehensive picture of the patient’s condition.

Diagnostic Accuracy and Efficacy of Chatbots

Nazareth et al [48] found that a chatbot can help identify high-risk patients for hereditary cancer syndromes. A total of 27.2% (n=14,850) of the chatbot users met the criteria for genetic testing, and 5.6% (n=73) of the chatbot users had a pathogenic variant. Ni et al [49] reported that Mandy, a chatbot, automates history-taking, understands symptoms expressed in natural language, and generates comprehensive reports for further medical investigations, with varying degrees of accuracy depending on the disease category. Hennemann et al [45] reported that the app-based symptom checker with an AI chatbot showed agreement with therapist diagnoses in 51% (n=25) of cases for the first condition suggestion and in 69% (n=34) of cases for the top five condition suggestions. Jungmann et al [47] tested a health app’s diagnostic agreement with case vignettes for mental disorders, pointing to the need for improvement in diagnostic accuracy, especially for mental disorders in childhood and adolescence.

Patient Perceptions and Acceptance of Chatbots

Hong et al [46] reported that most primary care patients believed that chatbots could help clinicians better understand their health and identify health risks. Ireland et al [28] found that the development of the Edna tool, an AI-based chatbot that interacts with patients via speech-to-text, signifies progress toward creating digital health processes that are accessible, acceptable, and well-supported, enabling patients to make informed decisions about additional findings. Heald et al [27] highlighted the feasibility of using chatbots for increasing genetic screening and testing in individuals at risk of hereditary colorectal cancer syndromes.

Challenges and Limitations of Chatbots

Reis et al [51] noted the importance of managing user resistance and fostering realistic expectations when implementing AI-based history-taking tools. Frick et al [42] found that patients preferred to disclose medical information to a physician rather than a conversational agent.

Effectiveness on Chatbots

Faqar-Uz-Zaman et al [41] found that classic patient-physician interaction was superior to an AI-based diagnostic tool applied by patients. However, they also noted that AI tools can benefit clinicians’ diagnostic efficacy and improve the quality of care. Schneider et al [52] found that a chatbot-supported anamnesis could save significant time by 57.3%, in assessing Hymenoptera venom allergies with high completeness (73.3%) and patient satisfaction (75%). Wang et al [29] demonstrated that technological support for documenting family history risks can be highly accepted, feasible, and effective.

Discussion

Principal Results

This systematic review highlights that the use of chatbots can improve medical history–taking. Results of the included studies have shown that chatbots can facilitate data collection while increasing patient engagement and satisfaction [39,49]. Chatbots show value, especially in collecting structured data such as family history [29,50,53]. As highlighted, the collection of family history benefits significantly from chatbot automation due to the simple nature of their queries, which typically require binary responses. This area contrasts with the challenges of collecting data on undiagnosed symptoms, where patient responses are inherently more nuanced and variable. The inherent abilities of chatbots to handle yes or no questions efficiently and without misinterpretation make them particularly valuable in this context, minimizing human error and optimizing the data collection process. Several studies have highlighted that chatbots provide a more engaging patient interaction, often perceived as less intimidating than traditional face-to-face conversations [27,46]. This interaction is crucial as it motivates patients to disclose more comprehensive health information, which can lead to better health outcomes. While chatbots excel at retrieving and conveying information through interactions that require limited context, their capabilities remain limited when it comes to more nuanced understanding and complex emotions. Research has shown that specific sensitive topics are best-discussed face-to-face with a human, where building trust is paramount [42]. Chatbots, on the other hand, offer relief through constant availability and allow patients to share details from any location and at any time, which can expand access—especially for urgent needs that require quick access to medical history [41,53]. This expanded access aims to improve care, especially in cases where timely data can make the difference between outcomes. In addition, chatbots support overburdened care providers by systematically presenting summarized patient data, potentially enabling faster and more accurate decisions [43,52]. Such support is invaluable in high-pressure situations requiring rapid action based on comprehensive information. These findings are consistent with previous research that emphasizes the ability of chatbots to capture patient reports in a structured, comprehensive way [3,22]. Their conversational design facilitates higher engagement and satisfaction through interactive discussions [4,50]. This contributes to improved documentation of patient histories. Furthermore, automated information capture has been confirmed to increase both the efficiency and accessibility of health care by simplifying reporting processes [21,39].

While chatbots already promise success in supporting diagnostic processes, the required level of accuracy must be achieved for complex medical scenarios that require in-depth understanding and sound clinical judgment. The limitations of current systems are highlighted in the studies by Hennemann et al [45] and Jungmann et al [47], highlighting the need to improve the algorithms and decision-making processes to manage complex health conditions.

While the seamless integration of conversational agents into clinical workflows requires robust data infrastructures and user-friendly interfaces, such integration can drive adoption among care providers and patients if done in a secure manner [48]. Customized chatbots are required to serve different patient audiences and different facilities. Addressing these needs can increase patient engagement and satisfaction [48,50].

However, the development of such technologies requires careful consideration [56]. Rushing to release chatbots without thorough refinement and validation can lead to inaccuracies and potentially detrimental outcomes. These hastily deployed chatbots run the risk of failing to understand complex medical situations and recommending incorrect diagnoses or treatments. The use of chatbots requires caution and rigorous testing or validation to minimize the risks [57-59].

Limitations

Although this systematic review provided useful insights, certain limitations must be acknowledged. As we only considered papers published in English, we may have overlooked important work published in other languages. In the future, a more comprehensive review that includes multilingual research could promote a more complete understanding of chatbots worldwide. The variability of study designs, patient groups, and health care contexts makes it difficult to draw definitive conclusions. Different studies, such as those by Denecke et al [39] and Faqar-Uz-Zaman et al [41], focused on different settings and patient groups, which influenced the results. Cross-sectional studies provide snapshots of usability, while RCTs provide robust evidence. Heterogeneity in demographics and health status also affects generalizability, as seen in the studies by Welch et al [53] and Wang et al [29]. Bias assessment frequently showed unmet STROBE criteria. Clear eligibility criteria and detailed methods could influence reliability. For example, Gashi et al [43] lacked defined selection criteria, and Jungmann et al [47] had a selection bias. Inconsistent reporting and lack of blinding in some RCTs, such as Wang et al [29], impaired internal validity.

The methodological quality of the included studies varied. At the same time, most observational studies demonstrated satisfactory quality, and a significant proportion fulfilled only some of the STROBE criteria. Additionally, the risk of bias assessment of the RCTs revealed a high risk of bias in one of the studies [41]. It is important to consider these limitations when interpreting the data and trying to understand how they relate to clinical practice. In addition, only published research has been included in this systematic review, which may lead to publication bias as studies with positive results are more likely to be published [41].

Future Directions

Based on the findings and limitations of this systematic review, future research should focus on conducting more standardized and well-designed studies in this field. Emphasizing rigorous study designs, such as RCTs, with larger sample sizes and standardized outcome measures will enhance the scientific validity of the research and provide more substantial evidence of the effectiveness of chatbots in history-taking. Standardized outcome measures between studies are crucial for better comparability. Future studies should use measures such as diagnostic accuracy, patient satisfaction, engagement, and usability ratings. Instruments, such as the system usability scale or the technology acceptance model, could be used. Further investigation is needed to explore the specific contexts and patient populations where chatbots for history-taking may be most effective [29,50,53]. Different medical areas and health situations may present special considerations and challenges that could influence the implementation and acceptance of chatbot-based systems for taking medical histories, such as in the case of older people due to a more limited technical affinity or long medical histories in people with chronic illnesses.

Moreover, future research should address the challenges and limitations identified in this review. Efforts should be made to minimize bias and improve the methodological quality of studies. Conducting studies with more homogeneous patient populations and using consistent outcome measures would enhance the comparability and generalizability of the findings [39].

Finally, it would be valuable to explore the integration of chatbots with other technologies or interventions to optimize the history-taking process. The integration of chatbots with modern technologies, such as NLP, machine learning algorithms, and decision support systems, has the potential to significantly improve history-taking [21,46,51]. NLP could improve the ability to understand and interpret patient responses to the chatbot. The interactions will be more fluid and intuitive. Machine learning algorithms can be used to continuously improve chatbot responses based on patient interactions. This could lead to more accurate and personalized information. The integration of decision support systems can provide health care providers with real-time evidence-based recommendations. Research designs to investigate these integrations could include comparative studies for measuring differences in diagnostic accuracy, patient satisfaction, and efficiency between 2 groups. One group could use a simple chatbot, and another group could use an advanced chatbot with integrated NLP and machine learning.

Conclusions

The systematic review provides an insightful overview of the use of chatbots in medical history–taking. The results show that chatbots can increase data completeness and user satisfaction. This can encourage patient engagement, and more accurate assessment can be achieved in a reduced timeframe. Chatbots can be used in primary care before the face-to-face visit. This would not only reduce the workload of medical staff but also enable more targeted interaction between patients and physicians. Future research should focus on different areas to improve the use of chatbots for medical history–taking. Larger studies and RCTs are essential for adequate validation. The use of chatbots needs to be investigated in different health care settings and with different patient groups, for example, in patients with chronic diseases, mental illness, or older patients and in people who are not tech-savvy. Another area that needs to be considered is analyzing the impact of chatbots on workflows in clinics or practices and the change in the doctor-patient relationship. In addition, data protection and security issues must be clarified to ensure the protection of patient data, especially considering the latest developments in AI models. These offer new opportunities for more precise and personalized interactions. Research should optimize these models for history-taking and integrate them into decision support systems for real-time evidence-based recommendations. If these areas are addressed, chatbots can significantly transform health care by improving efficiency, accuracy, and patient engagement, especially for underserved patient populations, as well as chronic disease management and real-time symptom assessment.

Acknowledgments

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Data Availability

All data generated or analyzed during this study are included in this published article. All aggregate data collected for this review are available from the corresponding author upon reasonable request.

Authors' Contributions

MH conceptualized and designed the analysis, collected the data, performed the screening and analysis, and was the primary author of the article. SS served as the second reviewer for screening and quality appraisal. AZ critically reviewed and provided feedback on the paper.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategies conducted, overview of studies, quality assessment of included studies.
[PDF File (Adobe PDF File), 324 KB-Multimedia Appendix 1]

Multimedia Appendix 2

PRISMA Checklist.
[PDF File (Adobe PDF File), 20 KB-Multimedia Appendix 2]

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Abbreviations

AI: artificial intelligence
NLP: natural language processing
PICOS: participants, interventions, comparators, outcomes, and study design
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

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ORIGINAL RESEARCH

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Hybrid care potential of teledermatology: The importance of linking digital and physical practice and acceptance of online services: A cross-sectional study

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Abstract

Background and Aims: Telemedicine, including teledermatology, has become a central component of modern medicine. Its importance, especially during the COVID-19 pandemic, underlines its potential to optimize access to dermatological care. The study aims to assess the potential of teledermatology, understand the importance of linking digital and physical practices, and analyze the adoption of online services based on participants' demographic and experiential factors.

Methods: This cross-sectional survey was conducted among users of the telemedicine platform from July 2022 to March 2023. The platform ("OnlineDoctor") allows users to contact dermatologists for remote dermatological consultations. The survey included questions about the participants' dermatological concerns, their reasons for using teledermatology, their satisfaction with the recommendations and their willingness to continue using telemedicine in the future. Data was collected via the RedCap online platform. Descriptive statistics and regression analyses were carried out.

Results: Overall, 1141 people participated in the study (mean age 44.0 years [SD 14.6], 61.4% women). Results showed that 52.7% of participants with skin conditions had not consulted a dermatologist in the previous year. Shorter waiting times and the lack of face-to-face appointments were the main reasons for using the online platform. In total, 77.6% ($n = 885$) of participants indicated they would use teledermatology as their first choice if they had an upcoming skin condition. Age, gender, and satisfaction with previous consultations impacted the use of teledermatology as the first choice for future skin conditions.

Conclusion: Teledermatology is characterized by various benefits, including reduced waiting times and improved accessibility to treatment. Nevertheless, the study underscores the importance of a hybrid care approach involving direct interaction with physicians. Teledermatology can be transformative in meeting dermatologic needs, mainly when traditional face-to-face consultation is limited. A deep understanding of user preferences and widespread adoption of digital services can pave the way for the successful adoption of teledermatology platforms, improving healthcare accessibility and efficiency.

KEYWORDS
digital health, digital medicine, hybrid care, online consultation, teledermatology, telemedicine

1 | INTRODUCTION

Telemedicine refers to the remote transmission and use of digital data.[1] The digital management of dermatological conditions is teledermatology, a telemedicine subfield.[2] Telemedicine, in turn, is a part of digital medicine, encompassing both remote transmission and on-site data utilization. “eHealth” or “digital health” are used interchangeably to refer to digital medicine and nonmedical digital procedures in the healthcare sector. In telemedicine, two central technical systems can be employed: (i) “store and forward” (S&F) and (ii) “real-time.”[3] In the S&F system, data is transmitted with intermediate storage and delayed forwarding, whereas, in the real-time application, data is transmitted in real-time.

Teledermatology has gained increasing significance in recent years, particularly during the COVID-19 pandemic when many patients with chronic or malignant skin conditions avoided in-person consultations and instead opted for teledermatology services, leading to a significant increase in utilization.[4–8] The growing importance of teledermatology can be attributed, among other reasons, to the fact that a substantial portion of the population requires dermatological care annually, especially for chronic skin conditions such as psoriasis, atopic dermatitis, or hidradenitis suppurativa.[7–9] In an era characterized by profound demographic shifts and evolving dermatological healthcare trends, teledermatology assumes a pivotal role. The field of dermatology care is going through changes due to the increasing prevalence of skin conditions in the population, particularly among the aging population.[10] Additionally, there is a decline in the number of dermatology specialists as the proportion of old healthcare professionals is increasing. Given capacity constraints, this demand can only be met to certain extent, making teledermatology a potential solution to meet future healthcare needs.[2,11,12] As stated in the S2k guideline “Teledermatology,” the teledermatological care of patients with psoriasis or atopic dermatitis, particularly the monitoring of disease progression through photos and videos, is effective and beneficial, provided that these procedures are technically, organizationally, and professionally implemented.[2] The guideline also demonstrates that digital documentation and assessment of wound conditions are not inferior to in-person documentation and analysis.[2]

Teledermatology can be applied for various functions (e.g., triage, consultation, diagnosis) involving different groups of individuals (e.g., patients, general practitioners, nurses) in different settings (e.g., hospitals, clinics, homes) using various technologies (e.g., smartphones, computers).[2] Teledermatology is expected to offer relative advantages in healthcare, such as reducing avoidable consultations, improving timely and spatial access to medical experts, and reducing travel and waiting times for patients.[12]

Since the introduction of the first legislative basis (E-Health Act of 2015), the framework has been progressively established in recent years to enable the use and reimbursement of real-time video or S&F telemedical consultations. In particular, the amendment of the model professional code of conduct for physicians in 2018 has opened the market for telemedicine providers. In recent years, numerous teledermatology concepts have emerged that directly provide and bill for services to individuals.[4,13,14] From the users' perspective, when properly implemented, teledermatology can offer advantages such as faster availability of decision-relevant data, easier access to medical care, better integration of qualified experts, simplified organizational efforts, and increased participation.[11,15–21]

The aim of this study is to explore the potential of teledermatology to close gaps in dermatology care, with a particular focus on patient satisfaction, usage behavior, and preferences. In particular, the importance of linking digital and physical practices in dermatological care will be examined.

2 | METHODS

2.1 | Study design and setting

This cross-sectional study is based on the STROBE statement and corresponding guidelines. The study was conducted among users of a telmedicine platform ("OnlineDoctor"), with a store and forward system (S&F). This platform offers the possibility of a subsequent personal consultation if necessary.[22,23] The data was collected between July 2022 and March 2023 via the Research Electronic Data Capture (RedCap).[24,25] The study was reviewed and approved by the Ethics Committee of the Faculty of Medicine and Health, Technical University of Munich (Ref 2022-309-S-SR).

2.2 | Participants

The study encompassed users of the telemedicine platform who submitted dermatological queries between July 2022 and December 2022. Responses were collected until March 2023. After receiving their diagnosis and recommendations, participants were asked to complete the online study questionnaire. Platform users of any skin condition or complaint aged 18 years or older were considered eligible.

2.3 | Questionnaire

A standardized online questionnaire was used to record the demographic data of the participants, including age, gender, and place of residence (large town, medium-sized town, small town, and rural community). The questionnaire was pilot-tested with three dermatological patients from our clinic. Based on the test, the questionnaire was revised in to align it as closely as possible with the research question. The questionnaire assessed the importance of in-person dermatological consultations compared to remote teledermatological services. To better understand the acceptance and importance of dermatological care, usage patterns, user experiences, and preferences for teledermatology were analyzed. This approach enabled a comprehensive assessment of how patients perceive and utilized digital health solutions in dermatology (Tables 1–3).

2.4 | Data preparation

The age variable was divided into four different groups: 18 to 30 years, 31 to 45 years, 46 to 65 years, and over 65 years. Only respondents who completed at least 80% of all questions were analyzed.

2.5 | Statistical methods

The data was summarized by descriptive statistics, including frequencies, percentages, means, and standard deviations (SD). Prespecified analyses included regression modeling. Exploratory analyses involved subgroup analyses based on age and residence to further investigate patterns not hypothesized a priori.

Binary logistic regression was used to analyze the relationship between demographic variables (e.g., age, gender, and place of residence) as independent variables and the likelihood of using teledermatology for future skin changes as the dependent variable. Due to the small sample size, the category "diverse" was not included in the regression analysis. This could have limited the statistical possibilities for determining significant effects. In the logistic regression analysis, the place of residence was divided into two categories. The first category included large towns with a population of 100,000 or more. The second category included all other areas, such as medium-sized towns (20,000–99,999 inhabitants), small towns (5000–19,999 inhabitants), and rural communities (under 5,000 inhabitants). The categorization was chosen in order to compare areas with a large urban population with smaller towns or rural communities in the context of telemedicine. The distinction between large towns and rural allows the study aimed to account for potential differences in access to healthcare, use of telehealth and patient preferences. In areas where traditional face-to-face healthcare services are less accessible, telemedicine could play a more important role in bridging gaps in healthcare.

In addition, two scenarios were analyzed to account for any uncertainties in participants' responses. As part of this analysis, two scenarios were created to understand the potential impact of undecided responses on the results of our study. For scenario 1, we treated these undecided responses as agreeing ("yes") with the use of teledermatology, while for scenario 2, we treated them as disagreeing ("no"). By repeating the logistic regression analysis in these two different scenarios, we wanted to validate the robustness of our original results and understand whether different interpretations of the undecided responses might influence the overall conclusions of the study.

All results of the logistic regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The significance level was set at $p < 0.05$. In the data analysis, potential confounders were considered to control for variables that could influence the results. Data management and statistical analyses were performed using R version 4.2.1 and IBM SPSS Statistics 28 (IBM Corporation).[26,27]

TABLE 1 Demographics of participants.

	Category	*n* (%)
Age, mean 44.0 (SD 14.6)	18–30 years	222 (19.5)
	31–45 years	440 (38.6)
	46–65 years	381 (33.4)
	>65 years	98 (8.6)
Gender	Female	701 (61.4)
	Male	434 (38.0)
	Divers	6 (0.5)
Place of residence	Large town (≥100,000 inhabitants)	480 (42.1)
	Medium-sized town (20,000–99,999)	240 (21.0)
	Small town (5000–19,999)	188 (16.5)
	Rural community (<5000 inhabitants)	233 (20.4)

Abbreviations: *n*, number; SD, standard deviation.

3 | RESULTS

3.1 | Participants

Overall, 1293 participants started filling in the questionnaire. Of those, 152 were excluded from the analysis as they completed less than 80% of the questionnaire. A total of 1141 people were considered in the analysis. Most participants were 31–45 years old (38.6%) and 46–65 years old (33.4%), and 19.5% were between 18 and 30 years old. In addition, a smaller proportion of participants were over 65 years old (8.6%). The overall mean age of the participants was 44.0 years (SD 14.6) (Table 1). 61.4% of the participants were female, and the participants were from various types of communities, including large towns (42.1%), medium-sized towns (21.0%), small towns (16.5%), and rural communities (20.4%).

Among the 1141 participants, 52.7% had their last dermatologist visit over 12 months ago, and 8.6% had never visited a dermatologist (Table 2). The mean time to reach the dermatologist was 28.7 min. Nearly half of the participants (47.4%) preferred visiting a fixed

TABLE 2 Summary of results (general questions).

Question/response options	*n* (%)
Last time you personally visited a dermatologist?	
I have never personally visited a dermatologist	98 (8.6)
<1 month	110 (9.6)
<6 months	178 (15.6)
<12 months	154 (13.5)
>12 months	601 (52.7)
How much time did it approximately take you to get to this dermatologist?	
<15 min	233 (20.4)
15–29 min	342 (30.0)
30–60 min	416 (36.5)
>60 min	46 (4.0)
Missing	107 (9.4)
Do you have a fixed practicing dermatologist (i.e., the one you usually visit)?	
Yes	541 (47.4)
No	500 (43.8)
Missing	100 (8.8)
How important is it for you to have personal contact with a physician on site?	
Very important	278 (24.4)
Important	491 (43.0)
Neither	228 (20.0)
Not important	125 (11.0)
Not at all important	17 (1.5)
Missing	2 (0.2)
Percentage of respondents considering personal on-site physician's contact important by age group ($p < 0.001$)	
18–30 years	114 (51.3)
31–45 years	283 (64.5)
46–65 years	287 (75.5)
>65 years	85 (86.8)
Percentage of respondents considering personal on-site physician's contact important by place of residency ($p < 0.004$)	
Large town (≥100,000 inhabitants)	294 (61.4)
Medium-sized town (20,000–99,999)	172 (71.7)
Small town (5000–19,999)	133 (70.8)
Rural community (<5000 inhabitants)	170 (73.3)

TABLE 3 Survey results on patient experience with teledermatology and follow-up actions.

Question/response options	*n* (%)
Was this the first time you used teledermatology (i.e., digital technologies for the medical assessment of a skin change)?	
Yes	975 (85.5)
No	142 (12.4)
Missing	24 (2.1)
How often have you used teledermatology?	
1 time	33 (2.9)
2 times	79 (6.9)
3 times	17 (1.5)
4 times	7 (0.6)
>5 times	6 (0.5)
Missing (most users were first time users)	999 (87.6)
What was the primary reason you used the platform? (multiple choice)	
Shorter wait time/no wait time	406 (35.6)
I didn't get an appointment at a dermatological practice	357 (31.3)
Use regardless of time	136 (11.9)
Use regardless of location	87 (7.6)
I wanted to see how teledermatology works	47 (4.1)
I wanted to get a second opinion	42 (3.7)
Other	42 (3.7)
Missing	24 (2.1)
The following question does not refer to the OnlineDoctor diagnosis, but to the period before it: Do you already have one or more skin diseases that have been diagnosed independently of the online consultation?	
Yes	451 (39.5)
No	666 (58.4)
Missing	24 (2.1)
Have you used OnlineDoctor due to symptoms of these skin conditions?	
Yes	204 (17.9)
No	247 (21.6)
Missing	690 (60.5)
How much time has passed between the first symptoms of the skin condition and the use of the online consultation?	
Within 24 h	59 (5.2)
1–7 days	276 (24.2)
8–30 days	247 (21.6)
1–6 months	316 (27.7)
Over 6 months	110 (9.6)
Missing	133 (11.7)

TABLE 3 (Continued)

Question/response options	*n* (%)
How important was it for you to be able to choose the dermatologist yourself?	
Very important	341 (29.9)
Important	326 (28.6)
Neither important nor unimportant	220 (19.3)
Not important	154 (13.5)
Not important at all	57 (5.0)
Missing	43 (3.8)
Based on what criteria did you choose the dermatologist?	
The dermatologist is near me	461 (40.4)
I knew the dermatologist before	269 (23.6)
I have chosen any dermatologist	253 (22.2)
Other	115 (10.1)
Missing	43 (3.8)
How did you like the online consultation compared to an in-person consultation?	
Much better	97 (8.5)
Better	226 (19.8)
About the same	532 (46.6)
Worse	108 (9.5)
Much worse	35 (3.1)
Can't say	99 (8.7)
Missing	44 (3.9)
How likely are you to use teledermatology first for future skin changes?	
Very likely	617 (54.1)
Somewhat likely	268 (23.5)
About 50–50	144 (12.6)
Somewhat unlikely	38 (3.3)
Very unlikely	31 (2.7)
Missing	43 (3.8)
Did the dermatologist recommend scheduling an additional in-person appointment after the online consultation?	
No	655 (57.4)
Yes	437 (38.3)
Missing	49 (4.3)
Have you (regardless of the dermatologist's recommendation) scheduled a personal appointment with a dermatologist after the online consultation?	
No	815 (71.4)
Yes	277 (24.3)
Missing	49 (4.3)

TABLE 3 (Continued)

Question/response options	*n* (%)
Why did you schedule a personal appointment? (multiple choice)	
To conduct further examinations (e.g., swab)	123 (30.5)
To initiate a therapy	75 (18.6)
To clarify existing uncertainties after the recommendation	73 (18.1)
To collect a prescription	66 (16.4)
To seek a second opinion	34 (8.4)
Other	32 (7.9)
Did you receive an appointment with the same dermatologist?	
Yes	138 (50.0)
No	92 (33.3)
The dermatologist is not in my area	46 (16.7)
How long did you have to wait for the appointment?	(Percentage of all patients who scheduled an appointment at any dermatologist $n = 277$)
Less than 7 days	116 (41.9)
7 days or more	23 (8.3)
Less than 4 weeks	33 (11.9)
4 weeks or more	102 (36.8)
Missing	3 (1.1)

Abbreviation: *n*, number.

practising dermatologist, and a substantial 67.4% considered personal contact with an on-site physician to be either "important" or "very important." The data shows a clear age-related trend in the importance of having personal on-site physician contact, with the highest percentage (86.8%) found among respondents aged over 65, followed by the 46–65 age group (75.5%), 31–45 age group (64.5%), and the 18–30 age group (51.3%) ($p < 0.001$). In large towns, 61.4% of respondents considered on-site physician contact important, while in medium-sized towns, 71.7% valued personal on-site physician contact. In small towns, 70.8% indicated this significance, and in rural communities, the highest percentage, at 73.3%, regarded personal on-site physician contact as crucial ($p < 0.004$).

The participants were asked whether they had been diagnosed with a skin condition before. The most common conditions were eczema (16.2%, $n = 185$), rosacea (5.4%, $n = 62$), and acne (5.1%, $n = 58$); Figure 1). Out of the 451 participants who reported having been diagnosed with one or more skin conditions independently of online consultation, 204 (45.2%) indicated that they had used online consultation due to symptoms of the mentioned skin conditions. When asked how much time elapsed between the first symptoms of the skin condition and the use of the online consultation, the answers varied greatly: 27.7% of participants used the online

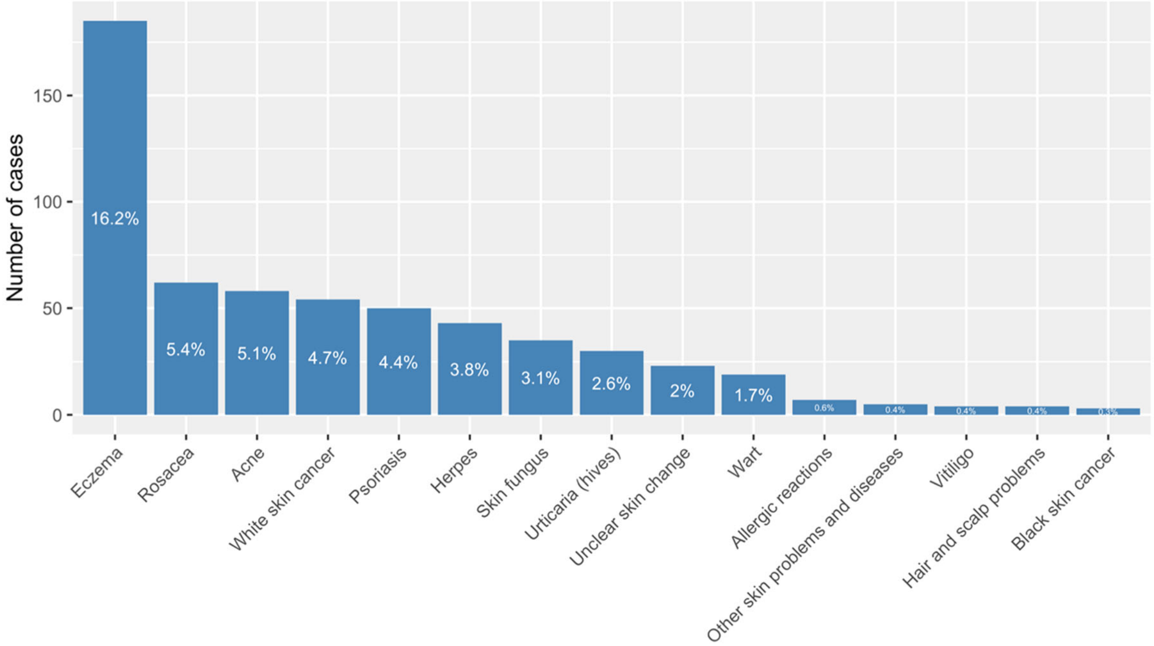

FIGURE 1 Apart from the online consultation, have you already been diagnosed with one or more skin conditions?.

consultation 1–6 months after the first symptoms, and 24.2% (*n* = 276) sought a consultation within 1–7 days.

Many respondents (85.5%, *n* = 975) were using teledermatology for the first time, while only 12.4% (*n* = 142) had used it previously (Table 3). The main reason for choosing teledermatology was shorter waiting times (35.6%, *n* = 406), followed by the impossibility of getting an appointment at a dermatology practice (31.3%, *n* = 357). Overall, 58.5% (*n* = 667) of respondents considered it important or very important to select their dermatologist. Regarding actual selection, 40.4% (*n* = 461) preferred a dermatologist in their area, and 23.6% (*n* = 269) chose a dermatologist they already knew. Comparative analysis of online versus in-person consultation revealed that 46.6% (*n* = 532) found the online experience to be about the same as in-person consultation, with 28.3% (*n* = 323) reporting it as better or much better. Most respondents (77.6%, *n* = 885) reported they are likely to use teledermatology for future skin changes.

Following the online consultation, 24.3% (*n* = 277) of respondents confirmed they had scheduled an in-person appointment with a dermatologist. However, only 18.9% (*n* = 216) of respondents were recommended to schedule an appointment by the physician. The primary reasons were to conduct further examinations (30.5% of those who scheduled an appointment, *n* = 123) and to initiate therapy (18.6%, *n* = 75). Of the 216 respondents who were recommended to schedule an appointment, 27.8% did not receive an appointment with the same physician, and 57.90% received an appointment. 14.4% indicated that the dermatologist is not in their vicinity.

87.0% of the participants were satisfied with the recommendation, while 10.2% were dissatisfied. When asked about their satisfaction with the quality of the healthcare service they received, most participants (89.1%) reported being satisfied. However, 8.6% of the participants were dissatisfied. Regarding the convenience of use (e.g., time-independent use), most participants (95.1%) were satisfied. A smaller percentage of participants (3.7%) were dissatisfied (Figure 2).

3.2 | Likelihood of opting for teledermatology as first choice

Scenario 1: Undecided responses (“about 50 to 50”) were categorized as “Yes.”

Gender did not significantly impact the likelihood of choosing teledermatology as the first choice for future skin changes (OR = 1.658, 95% CI [0.822, 3.342], *p* = 0.158; Table 4). Respondents over 65 exhibited a significantly lower inclination to opt for teledermatology compared to the reference group of 18-30 years (OR = 0.085, 95% CI [0.021, 0.345], $p < 0.001$). Additionally, individuals residing in rural areas showed a decreased likelihood of selecting teledermatology (OR = 0.371, 95% CI [0.191, 0.721], *p* = 0.003). Dissatisfaction with medical recommendations showed a significant association with a lower likelihood of choosing teledermatology as a first choice in the future (OR = 0.013, 95% CI [0.006, 0.027], $p < 0.001$).

Scenario 2: Undecided responses (“about 50 to 50”) were categorized as “No.”

Males were significantly more inclined to opt for teledermatology as the first choice for future skin changes (OR = 1.545, 95% CI [1.078, 2.215], *p* = 0.018) than the other reference groups. Age groups displayed substantial variations, with respondents aged 46-65 years (OR = 0.486, 95% CI [0.291, 0.814], *p* = 0.006) and those over 65 years (OR = 0.360, 95% CI [0.178, 0.727], *p* = 0.004) showing a

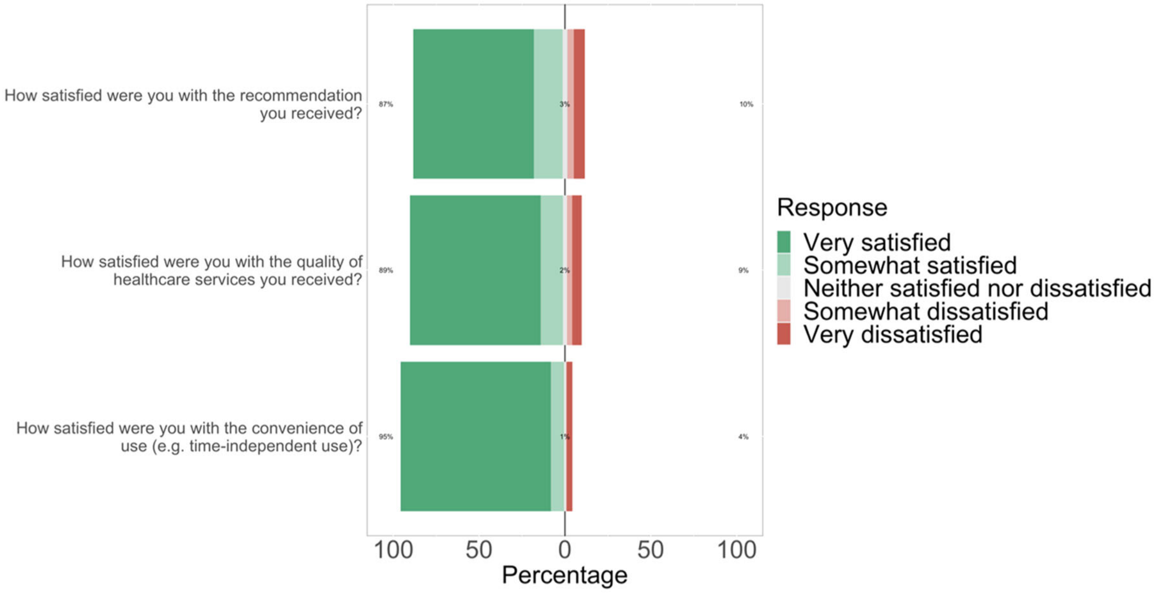

FIGURE 2 Satisfaction with the consultation.

reduced likelihood of choosing teledermatology compared to the reference group (18–30 years). However, the place of residence did not significantly influence this decision (OR = 0.991, 95% CI [0.701, 1.403], $p = 0.961$). Dissatisfaction with medical recommendations showed a significant association with a lower likelihood of choosing teledermatology as a first choice in the future (OR = 0.088, 95% CI [0.057, 0.136], $p < 0.001$).

Individuals who are younger and satisfied with previous recommendations are more likely to choose teledermatology as their primary option for future dermatological needs (Figure 3).

4 | DISCUSSION

4.1 | Principal findings

The key findings of this study emphasize the potential of teledermatology to close gaps in dermatological care. This applies in particular to users who have not seen a dermatologist in the last year. While satisfaction with teledermatology services is high, factors such as age, gender, place of residence, and satisfaction with previous recommendations play an important role. These factors influence the decision to use teledermatology as the first choice for future skin problems.

4.2 | Teledermatology usage patterns

The analysis of teledermatology utilization is consistent with the existing literature and hightlights growing potential of teledermatology to address the unmet need for dermatology services.[28–31] A high proportion of participants in our study had not seen a dermatologist in the past year, which is in line with other results showing that teledermatology effectively closes this gap, particularly in underserved and rural areas.[31] This highlights the role of teledermatology in improving access to quality care and reducing waiting times, also shown in the literature.[28,29]

Furthermore, our study highlights the increasing willingness of people to use digital solutions for skin health assessment, with a remarkably high proportion of first-time users. This trend is in line with the general realization that teledermatology can increase the efficiency of clinics and provide a valuable alternative, especially when traditional in-person appointments are unavailable or involve long waiting times.[32] Although patient satisfaction with teledermatology services remains high, it must be recognized that their success depends on the commitment of dermatologists.[31] The positive perception of teledermatology as a valuable tool is consistent with the existing literature.[32] Nevertheless, it is important to point out that further research is needed to gain a solid understanding of its effectiveness and accuracy.[30]

4.3 | Patient preferences and importance of on-site physician contact

Our findings on patient preferences underscore the continued importance of on-site physician contact in dermatology care. Many participants value face-to-face interaction with their healthcare provider, which aligns with previous research indicating different preferences depending on demographic factors such as age and place of residency.[33,34] Younger people favour digital health solutions, while older patients prefer face-to-face consultations. In addition, the preferences of urban and rural residents differ, with rural residents often valuing teledermatology less than their urban counterparts. This highlights the complex interplay of factors in

TABLE 4 Results of the binary logistic regression—Likelihood of teledermatology use as first choice (n = 1093).

How likely are you to use teledermatology as your first choice for skin changes in the future?—Undecided responses categorized as “Yes.” $p < 0.001$, $R^2 = 0.165$, Nagelkerke $R^2 = 0.470$

	OR	95% CI	p Value
Gender (Reference: Female)	1.658	(0.822, 3.342)	0.158
Age group (Reference 18–30)			
Age group 31–45	0.400	(0.152, 1.049)	0.063
Age group 46–65	0.435	(0.160, 1.187)	0.104
Age group > 65	0.085	(0.021, 0.345)	<0.001
Residency (Reference: Urban)	0.371	(0.191, 0.721)	0.003
Not satisfied with recommendation (Reference: Satisfied)	0.013	(0.006, 0.027)	<0.001

How likely are you to use teledermatology as your first choice for skin changes in the future?—Undecided responses categorized as "No." $p < 0.001$, $R^2 = 0.119$, Nagelkerke $R^2 = 0.193$

	OR	95% CI	p Value
Gender (Reference: Female)	1.545	1.078–2.215	0.018
Age group (Reference 18–30)			
Age group 31–45	0.768	0.460–1.281	0.311
Age group 46–65	0.486	0.291–0.814	0.006
Age group > 65	0.360	0.178–0.727	0.004
Residency (Reference: Urban)	0.991	0.701–1.403	0.961
Not satisfied with recommendation (Reference: Satisfied)	0.088	0.057–0.136	<0.001

Note: Nagelkerke R2 goodness of fit.

Abbreviations: CI, confidence interval; OR, odds ratio.

patient decision-making, including the severity of the dermatologic condition, the nature of the patient-physician relationship, and practical considerations such as waiting times for an appointment. These findings highlight that while teledermatology offers significant benefits, in many cases, it should be seen as a complement to, rather than a replacement for, traditional face-to-face consultations.[35,36]

4.4 | Patient satisfaction and future adoption

A high level of satisfaction was reported among participants. Other studies on telemedicine consistently show a high level of satisfaction with telemedicine, with patients reporting convenience, shorter waiting or travel times, and cost savings as the main reasons.[37–41] 77.6% of participants indicated their likelihood to choose teledermatology for future skin changes, underscoring the potential for continued adoption of online dermatological services. Following the online consultation, most participants indicated they did not arrange a personal appointment with a dermatologist. The findings suggest a substantial level of trust in teledermatological consultations and underscore their perceived effectiveness in providing dermatological consultation. The results align with the general trend in digital health, which emphasizes the increasing reliance on remote health services.[31,42,43]

Binary logistic regression analysis provided valuable insights into the factors influencing respondents' preference for teledermatology as a first choice to treat future skin changes. These findings are consistent with existing literature suggesting that younger people and certain demographic groups are more likely to use digital health services.[44–47] Targeted information campaigns may be needed to promote the uptake of teledermatology, particularly among older or rural populations. In addition, previous studies highlight the importance of educational programs and targeted initiatives to improve digital health literacy.[48–50]

4.5 | Strength and limitations

A key strength of this study is the systematic collection of patient preferences and usage behavior based on the STROBE guidelines. In addition, our sample reflects demographic characteristics that correlate strongly with the German population: an average age of 44 years and 77% of participants in nonrural regions, which is in line with national urbanization trends.[51–53]

On the other hand, there are limitations that need to be considered. The study is limited to users of a single teledermatology provider, which limits the generalizability of the results to a broader population and different teledermatology platforms. In addition, the exclusion of participants under the age of 18 could affect the representativeness of the results for younger age groups who may be more open to digital medicine.[54] Furthermore, the use of self-administered, non-validated questionnaires could affect the reliability of the data collected.

4.6 | Further development and regulation of teledermatology

The legal framework for teledermatology should be continuously developed for efficient and safe use.[55,56] Regulations on technical standards, reimbursement, and data protection are essential to improve access to healthcare while protecting patient privacy. Compliance with frameworks such as the General Data Protection Regulation (GDPR) in Europe is essential for teledermatology providers to minimize the risks associated with data breaches. A collaborative effort by policymakers, healthcare stakeholders, and technology experts is needed to continuously align existing

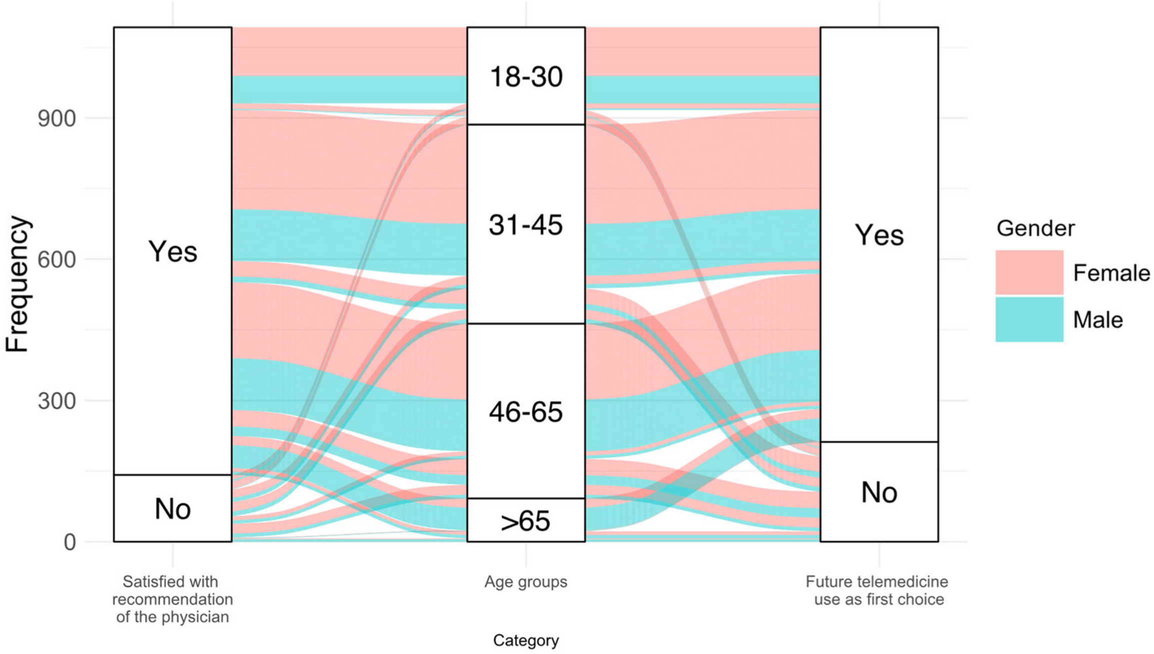

FIGURE 3 Satisfaction, age, gender, and future teledermatology use: Individuals who are younger and satisfied with previous recommendations are more likely to choose teledermatology as their primary option for future dermatological needs.

evidence-based guidelines in dermatology with available evidence, promote compliance, and foster a culture of privacy and transparency in teledermatology practice.[2,12,56]

5 | CONCLUSION

This study highlights the growing importance of teledermatology in meeting dermatology needs. The findings highlight the potential of online consultation to bridge gaps in dermatology care, particularly in scenarios where traditional face-to-face consultation is challenging. Although teledermatology offers shorter waiting times and better accessibility, the study underlines the continued importance of a hybrid approach with face-to-face physician interaction.

To successfully integrate teledermatology platforms, it is crucial to understand user preferences and consider the factors influencing digital service adoption. The study provides valuable insights for healthcare providers, policymakers, and technology developers to improve healthcare accessibility and operational efficiency in the evolving landscape of digital medicine.

Future research should focus on specific demographic groups and examine the long-term impact of teledermatology on patient outcomes. Despite its limitations, this study provides a foundation for ongoing discussions and advancements in the field and promotes the effective integration of technology into dermatology care.

AUTHOR CONTRIBUTIONS

Michael Hindelang conceptualized and designed the analysis, collected the data, performed the analysis, and was the primary author of the article. Linda Tizek conceptualized and designed the analysis and reviewed the paper. Christiane Harders conceptualized and designed the analysis and reviewed the paper. Leonie Sommer-Eska conceptualized and designed the analysis and reviewed the paper.

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CONFLICTS OF INTEREST STATEMENT

M. H. works at the Department of Dermatology and Allergy, Technical University of Munich, Munich, Germany and received no external funding. C. H. and L. S. currently work for OnlineDoctor 24 GmbH. L. T. worked at Technical University Munich and currently works for ViiV Healthcare.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article. All authors have read and approved the final version of the manuscript. Michael Hindelang had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis. All aggregated data collected for this paper are available from the corresponding author upon reasonable request.

TRANSPARENCY STATEMENT

The lead author Michael Hindelang affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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