

A Review of Technological Advancements in Strengthening Nurses' Competencies for Pain Management

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ABSTRACT

Effective pain management is a crucial aspect of nursing practice, and technological advancements have significantly enhanced nurses' competencies in this domain. This

narrative review explores the role of technology in strengthening nurses' pain management skills, focusing on the benefits, challenges, and future implications for nursing practice, education, and research. Various technological tools, such as electronic pain assessment instruments, smartphone applications, wearable devices, telehealth platforms, and virtual reality, have been employed to support accurate pain assessment, monitoring, and treatment. These tools provide objective data, facilitate real-time monitoring, enhance patient engagement, and enable remote consultations. However, the integration of technology in pain management also presents challenges, including data privacy concerns, technological proficiency, and ethical considerations. Nurses play a vital role in utilizing technology for pain management by assessing and monitoring pain, making informed treatment decisions, engaging patients remotely, and addressing ethical and privacy concerns. The implications for nursing practice include the need for technological competency and patient education. Nursing education should incorporate technology-related content and emphasize a patient-centered approach. Research is needed to evaluate the efficacy and effectiveness of technological interventions, assess usability and satisfaction, and address ethical considerations. In conclusion, technology has significantly enhanced nurses' pain management competencies, but a balanced approach considering benefits, challenges, and ethical implications is essential for optimal integration into nursing practice.

KEYWORDS: nurses, pain, pain management, Technological Advancements.

1. Introduction

Effective pain management is an essential element of nursing practice, enhancing nurses' critical thinking and decision-making abilities (Rababa & Al-Rawashdeh, 2021) to minimize patient suffering and improve overall well-being. Over the past 20 years, technological advancements have driven progress in pain control methods within the healthcare field (Strand et al., 2022). Technological approaches to pain management include a range of tools, such as wearable devices, virtual reality, computer-based training modules, mobile applications, and telehealth platforms, among others (Leroux et al., 2021; Mishra et al., 2022). These tools not only offer nurses opportunities to refine their skills in pain assessment but also support evidence-based strategies in monitoring patients' therapeutic responses. For example, Mahna, Ouda conducted research on evidence-based nursing interventions for managing pediatric pain in Africa, demonstrating that storytelling, reflexology, massage, cartoon videos, and music techniques can significantly reduce post-operative pain in children undergoing abdominal surgery; this study highlights the critical role of nurses in identifying and addressing patients' pain (Mahna, Ouda, & Sadek, 2019).

Furthermore, nurses' expertise in pain management significantly influences the quality of care delivered, particularly in managing opioid crises and participating in policy initiatives aimed at combating opioid addiction (Compton & Blacher, 2020). The integration of technology into pain management practices has strengthened nurses' competencies, knowledge, and judgment, ultimately resulting in improved patient outcomes and experiences.

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One major area where technology has influenced nurses' competencies in pain management is through the provision of accessible, personalized educational resources, such as mobile applications and computer-based modules that offer interactive and educational materials (Skiba, 2021). These resources provide nurses with up-to-date knowledge on pain assessment tools, pharmacological and non-pharmacological treatment options, and best practices in pain management. With these tools, nurses can expand their knowledge base and stay current with evidence-based practices.

In addition, advancements in technology offer platforms for simulation and virtual reality that allow nurses to practice pain assessment techniques and interventions within a realistic, controlled environment (Hadjiat & Marchand, 2022). Through virtual reality simulations, nurses can experience various pain scenarios, which enable them to refine their decision-making, enhance their critical thinking skills, and build confidence in their ability to effectively manage pain.

Despite these clear benefits, there are challenges associated with integrating technology into pain management practices. Nurses may face obstacles such as limited technological proficiency, time constraints, privacy concerns, and the need for continuous training. Addressing these challenges and ethical considerations is crucial for successfully incorporating technology into pain management methods. This narrative review explores how technology can enhance nurses' competencies in pain management, focusing on the benefits, challenges, and future practical implications.

Overview of Pain Concept

Pain is a prevalent and often primary symptom across many diseases, prompting individuals to seek medical care. Recognized as a factor with significant influence on all dimensions of a patient's life, pain is defined by the International Association for the Study of Pain as a negative perceptual and/or psychological experience, often expressed in terms of actual or potential tissue damage (Cohen et al., 2018).

In sub-Saharan Africa, where pain is frequently underdiagnosed and undertreated, approximately 80.5% of patients report experiencing some degree of pain, including severe pain, and 30.0% experience moderate to severe pain levels (Myhre et al., 2019). The intensity of pain is largely influenced by the underlying factors that trigger its occurrence.

In some cases, pain can be directly linked to a specific injury or illness, though at times, the source of discomfort may be unclear or ambiguous. Numerous diseases, including cancer, trauma, inflammation, and infection, often result in pain-related disorders or conditions, and pain may also signal a serious or life-threatening illness. Common sources of pain include headaches, sore throats, toothaches, burns, bruises, and cramps.

Researchers have identified several types of pain, including acute, chronic, neuropathic, and visceral pain (Scholz et al., 2019). It is also possible to experience multiple types of pain simultaneously, depending on the cause (Baranidharan et al.,

2020).

Approaches to managing each pain type vary, but earlier research found that a neural stimulus technique, BurstDR™, was effective in reducing visceral pain and improving the quality of life for patients suffering from chronic pain in internal organs (Baranidharan et al., 2020). Effective pain management can be challenged by several factors, such as the lack of standardized pain management guidelines, insufficient knowledge, and the complex nature of pain care (Clauw et al., 2019). Likewise, prior studies have identified key obstacles to effective pain management, including the tendency to overlook patient pain reports and the need for a comprehensive, multidimensional approach (Bazargan et al., 2021). Consequently, effective pain control requires knowledgeable healthcare providers with appropriate attitudes and assessment skills (Kahsay & Pitkäärvi, 2019). To further support quality pain management and improve patient quality of life, some researchers advocate for the integration of technology into pain management strategies (Chua et al., 2021).

Technologies for Pain Assessment

Various technological tools for pain assessment can support healthcare providers by providing objective data, thereby enhancing the accuracy of pain evaluations. The following technologies are commonly utilized in pain assessment:

Electronic Pain Assessment Tools and their Features

Digital tools have demonstrated their value in enhancing the quality of pain assessments by providing various electronic pain assessment options. These tools offer interactive methods for capturing the multidimensional aspects of pain, including its type, intensity, and location (Brigden et al., 2024). Hoti, Atee described the electronic Pain Assessment Tool (ePAT) as a service that incorporates automated facial assessment and other diagnostic indicators to assess the presence and severity of pain in dementia patients (Hoti et al., 2018). The ePAT tool employs a multimodal approach, enhancing the objectivity of pain assessment in non-communicative dementia patients by using automated facial recognition technology, digital integration, and computer vision algorithms.

Similarly, the Pain-QuILT tool, developed by Lalloo and Stinson, uses a dynamic anatomy-mapping technique to indicate the precise location of painful stimuli by aligning pain signals with specific body areas (Lalloo et al., 2014). For instance, this tool uses imagery to depict the quality of pain, such as a lit match to convey sensations of heat or burning.

1. Smartphone Applications for Pain Assessment and Documentation

The use of smartphone applications for pain assessment and documentation has risen in recent years. These apps are accessible and straightforward tools for both patients and healthcare providers to evaluate and document pain experiences. Examples of pain assessment smartphone applications include:

i. Pain Rating Scales: Numerous smartphone applications integrate built-in pain rating scales, such as the Numeric Rating Scale (NRS), Visual Analog Scale (VAS), and Faces Pain Scale (Sun et al., 2015). These scales provide standardized

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approaches for assessing pain, facilitating consistent tracking of pain levels over time (Cowen et al., 2015). Their effectiveness has been tested for different applications, such as in surgical contexts. For example, a randomized control trial evaluating the PANDA (Pain Assessment using a Novel Digital Application) app, which combines the numeric rating scale (NRS-11) and visual analog scale (VAS-101) digitally, found no significant difference when compared to a paper version of the scales (Chiu et al., 2019). Additionally, pain rating scales within smartphone applications can offer visual representations of pain data, as seen in interventions for pediatric chronic pain assessment where visualization takes the form of charts or graphs, helping both patients and clinicians to track progress, identify trends, and decide on optimal pain management strategies (Boerner et al., 2022).

ii. **Monitoring and Tracking:** Many smartphone applications offer features that allow users to track various pain-related symptoms, such as pain location, duration, quality, and associated factors (e.g., triggers and relieving factors). These features enable patients to provide more detailed descriptions of their pain. For instance, Karasneh, Al-Azzam developed a smartphone app for monitoring dysmenorrhea symptoms and related behavioral changes among female users during their menstrual cycles (Karasneh et al., 2020). The app is user-friendly and has an intuitive interface, making it accessible for a diverse user base (Koumpouros, 2022). Its ease of use also encourages patients to consistently participate in pain assessment and documentation.

iii. **Journaling and Diary:** Certain apps also offer journaling or diary functionalities, allowing users to maintain daily logs of their pain, activities, and any prescribed medications. This feature can help patients identify patterns, triggers, or factors that exacerbate pain. For instance, a smartphone headache diary app was created for individuals with migraine to log details about headache triggers and characteristics over three months (Park et al., 2016). This study indicated that headaches with identifiable triggers were associated with higher pain intensity, greater headache-related impairment, and medication discontinuation.

2. Wearable Devices for Real-time Pain Monitoring

Wearable technology now enables real-time monitoring of pain, providing valuable insights into pain intensity, patterns, and associated factors by recording physiological and behavioral data related to pain (Chen et al., 2021). These devices often include physiological sensors that can measure variables associated with pain, such as heart rate, skin conductance, muscle activity, and body temperature (Leroux et al., 2021). Wearables offer a unique advantage over other mobile health tools by providing objective data that can support the subjective evaluation of pain and stress levels (Chen et al., 2021). While research on wearable technology and pain is limited, some studies have investigated how pain patients' activity levels differ from those of healthy controls when monitored via accelerometers.

For example, wearable activity trackers have been studied in patients with rheumatic and orthopedic conditions, including osteoarthritis and lumbar pain, as demonstrated in 17 studies. Findings showed increased step count and time spent in physical

activity (Davergne et al., 2019). However, the study did not distinguish between increased activity due to pain management efforts and other factors. Nonetheless, pain levels increased in trials lasting over two months when compared to controls.

3. Telehealth and Telemedicine Applications in Pain Assessment

Telehealth and telemedicine are valuable tools for conducting remote pain assessments, enhancing patient access to pain management, particularly in remote or underserved areas (Ahmed Kamal et al., 2023). Telehealth and telemedicine applications are increasingly essential for pain evaluation, especially when in-person consultations are challenging or impractical. A primary objective of telehealth is to provide timely, proximal healthcare access by enabling rapid, remote evaluations, facilitating direct interaction between patients and healthcare providers, and minimizing unnecessary hospital visits (Perez et al., 2021). Remote consultations allow clinicians to engage with patients in real time, enabling the assessment of pain via video conferencing, where providers can visually observe the patient, ask relevant questions, and evaluate pain type and intensity (Ahmed Kamal et al., 2023). Through telehealth, patients can utilize self-reporting tools, such as questionnaires and pain rating scales, to communicate their pain experiences. Healthcare providers can collect detailed data on pain severity, location, quality, and associated factors through these self-report methods. Patients may also use digital imaging to capture photos or videos of painful areas, allowing clinicians to visually assess for any external signs—such as swelling, redness, or sores—that may be contributing to the pain (Hoti et al., 2018).

4. Virtual Reality Approaches to Pain Management

Virtual reality (VR) provides immersive, interactive, and visually engaging experiences that can redirect patients' attention away from pain by substituting discomfort with stimulating or calming environments, even for cancer patients who frequently endure chronic pain (Scates et al., 2020). By using VR headsets along with haptic gloves or controllers, users can fully engage in a dynamic 3D, 360-degree simulated environment, where they can move around and interact with tactile and sensory feedback. VR's potential to reduce or replace opioid use and analgesics presents significant clinical advantages for patients and healthcare providers alike (Lalloo et al., 2014). Over the past two decades, VR has proven effective for both short-term and long-term pain management (Ahmadpour et al., 2019).

VR serves as a powerful therapeutic tool with diverse applications, as it can alter brain circuits and neurotransmitter activity related to pain processing, reducing the intensity and unpleasantness of pain (Ahmadpour et al., 2019). By influencing the brain's ascending pain pathways, VR mitigates pain perception through attention redirection. A randomized controlled trial demonstrated VR's ability to engage and immerse healthy participants, supporting the theory of attentional distraction as a mechanism for VR's pain-relieving effects (Al-Ghamdi et al., 2019).

Additionally, VR is an effective non-drug pain management strategy that can decrease the need for pain medications, which is beneficial for those wishing to limit opioid dependence. VR can be employed as a standalone pain management tool or as a complementary approach to pharmacological treatments, thereby providing another

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viable pain management option. VR's capacity to substitute or lessen the need for analgesics is a significant benefit for both patients and clinicians (Al-Ghamdi et al., 2019).

Benefits of Utilizing Technology in Pain Monitoring

Generally, the use of technology, such as smartphone apps and telehealth platforms for pain assessment and documentation, offers practical and effective methods for tracking pain experiences. These technologies can encourage patient engagement and facilitate clear communication between patients and healthcare providers. Recent reviews suggest that technological advancements foster ongoing communication and monitoring among healthcare professionals (Ahmed Kamal et al., 2023; Osei & Mashamba-Thompson, 2021). Technology-enabled pain monitoring enables continuous and remote monitoring with objective measurements (Liao et al., 2019). Key benefits of technology-enhanced pain monitoring include:

1. Promotion of Objective Pain Assessment

Quantitative EEG (qEEG) employs computationally filtered signals to visualize brain activity patterns captured by electroencephalography (EEG), offering objective insights into pain response (Byrom et al., 2018). In another view, data collected through technology allows healthcare providers to gain a comprehensive understanding of a patient's pain experience, supporting more accurate diagnoses and individualized treatment plans, and helping assess the quality of care provided (Haleem et al., 2021).

2. Connectivity with Other Healthcare Solutions

Technological integration, such as linking pain monitoring systems with electronic health records (EHRs), promotes collaborative care and seamless data sharing between physicians and nurses, supporting a holistic approach to pain management (Dinh-Le et al., 2019). This integration ensures that all healthcare providers can access vital pain information, fostering coordinated care and collaboration among healthcare providers and patients' wearable devices (Dinh-Le et al., 2019). A telehealth platform integrated with an interoperable EHR system can directly impact the healthcare quadruple aim: better health outcomes, enhanced patient satisfaction, cost reductions, and improved provider expertise (Bodenheimer & Sinsky, 2014; Zhang & Saltman, 2022).

3. Continuous Pain Monitoring

Technology supports continuous monitoring of pain, enabling healthcare providers to track symptoms and medical outcomes promptly (Liao et al., 2019). This capability is especially useful for managing chronic pain conditions, such as those experienced in cancer, allowing healthcare providers to observe patterns, identify triggers, and evaluate treatment effectiveness over time.

4. Enhanced Patient Involvement in Pain Management

Technology-enabled pain monitoring encourages active patient engagement in pain management, thus enhancing patient involvement (Liao et al., 2019). In a cluster

randomized controlled trial at four hospices, the EMPOWER (Effective Management of Pain: Overcoming Worries to Enable Relief) program's preliminary efficacy was evaluated, showing benefits for both patients and caregivers (Cagle et al., 2015). By using apps, wearable devices, and other digital tools, patients can track their pain levels, symptoms, medication use, and lifestyle factors affecting their pain (Davergne et al., 2019; Leroux et al., 2021). Increased patient involvement fosters adherence to treatment plans and better health outcomes, empowering patients with a sense of control and accountability. For instance, the trauma-informed approach underscores the importance of involving patients in treatment planning and decision-making processes, contrasting with traditional care where patients have minimal input.

Overall, these technological benefits contribute to improved pain management, more personalized care, and better patient outcomes.

Limitations of Technology Application in Pain Management and Considerations

While technology presents numerous advantages for pain management, it also brings certain limitations and challenges that should be considered. The following points highlight key limitations and considerations for the effective use of technology in pain management:

Smartphone applications offer a promising avenue for pain management, but potential inaccuracies in self-reported data, inconsistency in app quality, and the need for evidence supporting app effectiveness and reliability pose notable limitations. Additionally, concerns about data privacy and security, as well as a general lack of expertise in the use of pain-related technology, are critical considerations before adopting any app (Schroeder et al., 2022).

For telehealth services, it is essential to consider certain limitations, including technological challenges, patients' comfort and familiarity with the platform, and the need for a stable internet connection. Ensuring patient confidentiality during telehealth sessions is also crucial, requiring providers to verify that staff members are adequately trained and adhere to privacy regulations (Houser et al., 2023).

Hasoon and Uris argue that telemedicine can impair clinicians' ability to conduct physical examinations, which are sometimes essential for accurately diagnosing pain sources (Hasoon et al., 2022). The limited in-person interactions between patients and medical staff, which can be instrumental when patients display concerns or unusual behaviors, such as substance misuse, also pose a challenge (Burroughs et al., 2020). Furthermore, telemedicine complicates opioid management by making it harder to perform random urine drug screenings or drug/pill counts effectively (Hasoon et al., 2022). Overall, telemedicine has encountered certain drawbacks across various specialties (Westbrook et al., 2015).

Ethical concerns also present challenges in technologically mediated pain management. Draper and Sorell emphasize the importance of responsible and ethical use of technology in pain management to prevent an overreliance on digital solutions at the expense of human interaction and personalized care (Draper & Sorell, 2017). Patient autonomy and informed consent are crucial when integrating technology-based interventions. Prior research indicates that caregivers' relationships with patients and their families may be negatively impacted or disrupted using digital

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devices (Robichaux et al., 2019). Additionally, significant ethical questions have arisen regarding the thresholds of pain and suffering that warrant intervention, as well as the potential for excessive treatment in managing pain and suffering. These ethical concerns contribute to the reluctance of some caregivers to integrate digital technology into patient care (Booth et al., 2021).

Nurses' Role in Utilizing Technology in Pain Management

As nursing practice evolves, technology is becoming increasingly integral. Innovations such as artificial intelligence, wearable monitors, and smart devices have expanded nursing roles, enabling higher levels of patient care through the integration of advanced technology into healthcare settings, homes, and nursing facilities. Below are key ways in which technology has impacted nurses' roles and practices.

1. **Pain Assessment and Monitoring:** Wearable monitors allow nurses to efficiently monitor patients while managing other responsibilities. These devices track vital signs like oxygen saturation, heart rhythms, and respiration rates. Notifications alert caregivers when patients require immediate attention, significantly reducing response times. Through technology-enabled pain assessment, nurses employ various tools, such as wearable devices, mobile apps, and electronic pain scales, to gather objective data and monitor pain over time.
2. **Decision-Making in Pain Treatment:** Nurses play a crucial role in selecting appropriate pain treatments. It is essential for nurses to be well-informed about pain assessment and treatment, maintaining objectivity and avoiding misconceptions to ensure effective pain relief. Samarkandi highlights those inaccurate beliefs, such as the assumption that patients may exaggerate pain or that pain is identifiable solely through health metrics, can impede effective care (Samarkandi, 2018). Thus, nurses must advocate for patients' needs, ensuring that technology is used with empathy and a patient-centered approach.
3. **Remote Patient Engagement:** Mobile applications enable patients to communicate with healthcare providers from their homes. Patients can update their information on these apps, while nurses offer guidance on various health issues, including pain management (FAAD, 2021). Nurses address patient concerns, provide information, and encourage the use of technological tools, helping patients gain confidence in managing their pain (Zhang & Saltman, 2022).
4. **Ethical and Privacy Considerations:** Nurses address the ethical implications of technology in pain management, safeguarding patient privacy, confidentiality, and informed consent when collecting and using pain-related data. They advocate for ethical technology use and remain vigilant about potential biases or disparities in care (Carvalho et al., 2018).
5. **Interdisciplinary Collaboration:** Nurses work closely with interdisciplinary teams to integrate technology into pain management strategies. They collaborate with physicians, pharmacists, physical therapists, and other healthcare professionals to ensure comprehensive pain care, sharing data and coordinating efforts (FAAD, 2021). Research supports that interdisciplinary approaches lead to improved patient

safety, reduced hospital admissions, and fewer complications and errors (Bendowska & Baum, 2023). For instance, many hospitals are adopting unified communication systems, allowing nurses to communicate in real-time with colleagues through badges or headsets, receiving emergency alerts, and instantly updating Electronic Medical Records (EMR) (FAAD, 2021).

Leveraging Technology in Pain Management: Implications for Nursing Practice, Education, and Research

The integration of technology into pain management has significant implications for nursing practice, education, and research. Below are some critical aspects for each area, contributing to nursing competency:

1. **Technological Competency:** As the field of pain management becomes increasingly technology-focused, nurses need to stay current with technological advances and understand how to apply them effectively. This includes familiarizing themselves with wearable devices, telemedicine platforms, virtual reality tools, and electronic pain assessment instruments to enhance pain control.
2. **Patient Education and Support:** Nurses play a pivotal role in educating patients on technology-assisted pain management methods. They should address patients' questions, provide thorough guidance on tool usage, and offer ongoing support.
3. **Curriculum Integration:** Nursing education should incorporate technology-related content into its programs. This involves introducing students to pain assessment tools, digital health platforms, and virtual reality applications for pain management, with practical instruction in technology-based monitoring and assessment.
4. **Patient-Centered Approach:** Technology education in nursing should emphasize patient-centered care. Students should learn how to communicate about technology use effectively, involve patients in decision-making, and address their specific needs.
5. **Efficacy and Effectiveness Studies:** Research is needed to evaluate the efficacy of various technological interventions for pain management, treatment adherence, and quality of life. Evidence-based best practices and recommendations can guide the integration of technology into nursing.
6. **Usability and Satisfaction Studies:** Research should also explore the ease of use of technological tools for pain management. This involves assessing patient and caregiver satisfaction, identifying barriers to technology adoption, and understanding factors that contribute to successful implementation.
7. **Ethical Considerations in Research:** Studies on the use of technology for pain management should address ethical concerns such as data privacy and security, informed consent, algorithmic bias, and equitable access.

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2. Conclusion

This review on the “Technological Advancements in Strengthening Nurses' Competencies for Pain Management” underscores the vital role technology plays in enabling nurses to provide comprehensive and effective pain care. An extensive review of scholarly articles from various databases reveals numerous ways in which technology has enhanced nurses' ability to assess, monitor, and treat pain.

Technological tools such as electronic health records (EHRs), mobile apps, virtual reality, and wearable devices have demonstrated significant benefits in supporting accurate pain assessment, tailoring treatment plans, and ensuring timely interventions. However, integrating technology into pain management requires a balanced approach. As technology advances, usability, accessibility, and ethical considerations are critical to equipping nurses to improve their pain management competencies effectively without introducing unnecessary risks. Technology-driven education initiatives are effective methods for enhancing nurses' expertise in pain management. The promotion of online resources, webinars, and interactive platforms can help nurses stay informed and skilled, ultimately leading to improved patient outcomes and more effective pain management strategies.

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