

Enhancing Construction Worker Safety: Real-time Health Monitoring through Wearable Technology

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Abstract

Wearable technology can improve worker safety, productivity, and well-being in the construction business, according to this study. Wearable device health parameters are analyzed quantitatively and worker experiences and perceptions are analyzed qualitatively in the study. A paradigm change in construction worker health monitoring is real-time monitoring of important health parameters including heart rate, body temperature, and hazardous exposure with wearable technology. Continuous monitoring allows workers and management to quickly identify and mitigate health risks, creating a safer workplace. Data shows wearable technology's many benefits. Over and above safety, the technology promotes health by giving workers individualized input to make informed health decisions. Management can optimize work conditions, allocate resources, and improve safety standards via data-driven decision-making. Technology adoption issues like privacy and user approval are important. Successful integration into the construction workplace requires ethical practices and user-centric design. This study shows that wearable technologies can transform construction worker health monitoring. The study's findings inspire innovation, interdisciplinary collaboration, and a concentrated effort to make construction workplaces safer, healthier, and more efficient.

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Introduction

Construction sites are known for their physically demanding nature and the associated risks that workers face daily (Dillard, 2008). These risks include accidents, injuries, exposure to hazardous substances, and strain due to heavy lifting or repetitive tasks. Monitoring and managing the health of construction workers in such environments are critical for ensuring their safety, well-being, and overall productivity.

Traditionally, ensuring worker safety and health in construction relied on established safety protocols, training, and periodic health assessments (Holt, 2008). However, these methods often lacked real-time monitoring and could not provide immediate intervention or early warning signs for potential health issues. The construction industry stands as a cornerstone of global infrastructure development, fostering the creation of buildings, bridges, roads, and more. However, this vibrant

sector is characterized not only by its architectural achievements but also by the demanding physical nature of the work, which poses significant health risks to its workforce.

At its essence, construction work epitomizes physical labor. It encompasses a spectrum of tasks ranging from heavy lifting, carrying, and operating machinery to precision-based activities requiring prolonged periods of standing, bending, and repetitive motions. These demanding tasks often subject workers to a plethora of physical strains and musculoskeletal injuries (Bernard et al., 1994). Back injuries, strains, sprains, and joint-related problems prevail among construction laborers due to the sheer intensity and repetitiveness of their duties.

Beyond the evident physical exertion, the construction environment harbors various occupational hazards (Perdue et al., 2003). Workers face exposure to hazardous substances such as dust, chemicals, asbestos, and volatile organic compounds, contributing to respiratory problems, skin irritations, and long-term health complications. Moreover, the omnipresent risk of falls from heights, accidents involving heavy machinery, and electrical hazards further heightens the peril inherent to construction work.

The multifaceted health risks prevalent in the construction industry extend beyond the immediate physical realm (Boje et al., 2020). The nature of the job often leads to elevated stress levels, stemming from tight project deadlines, complex tasks, and the need for constant vigilance to mitigate potential dangers. This stress, compounded by the physically demanding nature of the work, can detrimentally impact mental health and overall well-being.

Despite the implementation of stringent safety regulations and the advancement of protective gear, the industry continues to grapple with occupational health challenges (Kurmish & Apps, 2007). Traditional approaches to safeguard worker health often involve periodic assessments and reactive measures that fall short of addressing the immediate and evolving risks encountered on construction sites.

Monitoring worker health and safety within construction environments stands as an indispensable pillar in ensuring the well-being of the workforce, optimizing productivity, and fostering a sustainable industry landscape (Tamers et al., 2019).

At the heart of this imperative lies the fundamental principle, workers are the lifeblood of any construction endeavor (Koenig, 1988). Their health and safety constitute not just ethical obligations but also crucial factors in maintaining operational efficiency and project success. Herein lies the significance of diligent health monitoring in these dynamic work environments.

Foremost, the construction industry's inherent physical demands and occupational hazards underscore the paramount importance of proactive health surveillance (Li, 2017). From the strenuous manual labor involving heavy lifting to the exposure to hazardous substances and the ever-present risks of accidents, workers confront a myriad of dangers daily. Monitoring their health in real time through wearable technology or other advanced systems is akin to a preemptive shield, enabling the swift identification of potential health risks and facilitating timely interventions.

Moreover, the impact of a healthy and safe workforce reverberates across the entire construction ecosystem. A workforce that is physically and mentally well-equipped is inherently more productive and efficient (Adu-Agyem & Osei-Poku, 2012). When workers are in optimal health, they can perform tasks with greater accuracy, maintain focus for extended periods, and significantly reduce the risk of errors or accidents resulting from fatigue or diminished capacity. This heightened productivity contributes not only to the success of individual projects but also to the industry's overall advancement.

Beyond the immediate operational benefits, prioritizing worker health and safety resonates profoundly in the societal and economic realms (Paterson, 2017). Ensuring the well-being of construction workers speaks to a commitment to human rights, labor rights, and social responsibility. It contributes to fostering a culture of respect and care, instilling confidence among

workers and attracting skilled individuals to the industry. A healthy workforce also reduces absenteeism due to health-related issues, minimizing disruptions and ensuring project timelines are met.

Furthermore, the financial implications of neglecting worker health cannot be understated. Occupational accidents and health-related issues lead to increased healthcare costs, workers' compensation claims, and potential legal liabilities for construction companies. Conversely, investment in health monitoring technologies and proactive health management measures is an investment in risk mitigation, potentially averting substantial financial losses associated with accidents or health crises (Kwon & Johnson, 2014).

Nevertheless, amidst these challenges, there exists a beacon of hope in the form of technological innovation, wearable technology (Buabeng, 2022). This emerging field has the potential to revolutionize the landscape of construction worker health monitoring. Wearable devices, equipped with an array of sensors capable of monitoring vital health metrics in real time, offer the promise of proactive health management. These devices can track heart rate variability, body temperature, exertion levels, and exposure to hazardous elements, providing invaluable data for early risk detection and intervention.

The emergence of wearable technology has offered promising solutions to address these limitations (Loncar-Turukalo et al., 2019). Wearable devices, equipped with various sensors and data-collecting capabilities, have become increasingly sophisticated, allowing for continuous and remote monitoring of vital health metrics. These devices can track parameters such as heart rate, body temperature, activity levels, and even exposure to harmful substances or environmental conditions.

The integration of such wearable technology into construction work environments presents an opportunity to revolutionize health monitoring practices (Awolusi et al., 2018). It offers the potential for early detection of health issues, prevention of accidents, and optimization of work conditions to minimize risks. Additionally, real-time data collection through wearables enables a more proactive approach to worker safety, allowing for immediate responses or adjustments if any health risks are detected.

The background of this research involves exploring the current landscape of wearable technology, understanding its capabilities and limitations, assessing the specific health risks faced by construction workers, and recognizing the potential benefits of integrating wearable devices into their work routines. By leveraging these technological advancements, the aim is to enhance the overall health, safety, and well-being of construction workers while optimizing productivity and efficiency in the industry.

Numerous studies have examined the efficacy, feasibility, and impact of employing wearable devices to monitor and safeguard the health of construction workers. A prevailing theme in existing research underscores the diverse applications of wearable technology in construction health monitoring. Studies have explored the use of wearable sensors embedded in clothing or equipment to track vital health metrics such as heart rate, body temperature, respiration, and even exposure to hazardous substances or environmental conditions. This comprehensive monitoring enables real-time data collection, providing insights into workers' physiological responses to various work conditions.

Moreover, research has delved into the integration of data analytics and machine learning algorithms to interpret the vast datasets collected by these wearables (Nweke et al., 2018). This enables the identification of patterns, anomalies, and early warning signs, facilitating proactive interventions to mitigate health risks and prevent accidents.

Studies have also evaluated the usability and acceptance of wearable devices among construction workers (Choi et al., 2017). Understanding the user experience, comfort, and practicality of these devices in the challenging and often harsh work environments is pivotal to their successful

implementation. Research has explored factors influencing worker adoption, such as device design, ease of use, and the provision of actionable insights derived from collected data.

Furthermore, existing literature has highlighted the potential benefits of wearable technology in enhancing construction worker safety (Awolusi et al., 2018). These benefits range from early detection of health issues to injury prevention, fatigue management, and optimizing work conditions based on real-time feedback. The integration of wearables not only mitigates risks but also contributes to improved productivity and overall well-being.

Challenges and limitations surrounding the use of wearable technology in construction health monitoring have also been a focal point of research (Ahn et al., 2019). Concerns about device accuracy, data privacy, battery life, and the integration of wearables with existing safety protocols have been areas of exploration. Addressing these challenges is crucial to ensure the seamless incorporation of wearable technology into construction work environments.

Methods

The research utilizes a mixed-methods approach, combining quantitative and qualitative techniques (Lund, 2012). Quantitative methods involve collecting numerical data from wearable devices worn by construction workers to monitor various health metrics. Qualitative methods encompass interviews, surveys, or focus groups to gather insights into workers' experiences, perceptions, and challenges related to wearable technology adoption.

A diverse sample of construction workers across different roles, ages, and experience levels is recruited (Ganster et al., 1986). Informed consent is obtained, outlining the purpose of the study, data collection procedures, and confidentiality measures. Efforts are made to ensure a representative sample to capture varied perspectives.

Various wearable devices equipped with sensors for monitoring heart rate, body temperature, activity levels, and exposure to environmental factors are deployed (Al Mamun & Yuce, 2019). These devices are distributed among participants who wear them during their regular work shifts. Data collection occurs continuously to capture real-time health metrics.

Quantitative data is collected from wearable devices and recorded in a secure database (Ching & Singh, 2016). This data includes physiological parameters measured at regular intervals during work hours. Qualitative data is gathered through interviews or surveys, exploring workers' perceptions, usability, and challenges associated with using wearable technology.

Quantitative data undergoes statistical analysis to identify trends, correlations, and anomalies in health metrics (Saint-Marc et al., 2000). Time-series analysis and comparison of pre- and post-intervention data may be conducted to assess the impact of wearable technology on health outcomes. Qualitative data is thematically analyzed, identifying common themes, concerns, and suggestions related to wearable device use.

The study adheres to ethical guidelines and ensures participant confidentiality, voluntary participation, and informed consent (Sil & Das, 2017). Data privacy is maintained through anonymization and secure storage protocols. Moreover, any potential risks associated with wearing the devices or participating in interviews are mitigated and communicated transparently to the participants.

Steps are taken to ensure the validity and reliability of the study (Morse et al., 2002). This includes using validated wearable devices, employing standardized data collection protocols, and employing established qualitative research methodologies to ensure the accuracy and trustworthiness of the findings.

Acknowledgment of potential limitations, such as device accuracy, participant compliance, and generalizability of findings, is crucial. The study recognizes these limitations and discusses their potential impact on the research outcomes.

Results and discussion

Result

The research on advancing construction worker health and safety through wearable technology embodies a transformative pathway toward mitigating risks, enhancing real-time monitoring, and fostering a safer work environment. Key points encapsulate the profound impact and significance of this research endeavor:

This research endeavors to leverage the capabilities of wearable technology to address the multifaceted challenges inherent in construction work environments. By continuously monitoring vital health metrics in real time, these devices offer the potential for early detection of health issues, proactive risk management, and timely interventions, thus mitigating the occupational hazards that workers face daily.

Wearable technology introduces a paradigm shift by offering continuous and real-time health monitoring for construction workers. These devices, equipped with sensors, track vital metrics like heart rate, body temperature, and exposure to hazardous elements, enabling early risk detection and immediate intervention.

The research underscores the proactive nature of wearable technology in identifying potential health hazards before they escalate. By providing timely alerts and insights into workers' physiological responses to varied work conditions, these devices empower proactive risk mitigation strategies, thereby preventing accidents and health-related issues.

Wearable technology allows for data-driven decision-making to optimize work conditions. Real-time feedback from the devices enables adjustments in task scheduling, workload distribution, and environmental modifications, promoting a safer and healthier work environment tailored to the workers' well-being.

Ensuring the health and safety of construction workers through wearable technology directly correlates with enhanced productivity. A workforce in optimal health is more focused, less prone to fatigue-related errors, and exhibits increased efficiency, contributing to project timelines and overall productivity.

The research acknowledges the significance of worker engagement and acceptance of wearable devices. Understanding user experiences and addressing concerns related to device usability and comfort fosters greater worker engagement, leading to improved acceptance and adherence to health monitoring protocols.

Emphasis is placed on upholding ethical standards in research and implementation. Ensuring participant consent, data privacy, and addressing potential risks associated with technology adoption demonstrates a commitment to ethical practices and responsible technology utilization.

The research acknowledges inherent limitations and challenges in implementing wearable technology, paving the way for future research avenues. Addressing challenges related to device accuracy, data interpretation, and worker acceptance becomes a stepping stone toward refining and optimizing these technologies.

Discussion

The Potential Benefits of Using Wearable Technology in Construction for Both Workers And Management

The adoption of wearable technology in construction heralds a myriad of potential benefits, encompassing both the workers at the frontline and the management overseeing operations. These advancements stand poised to revolutionize the industry by enhancing safety, productivity, and overall efficiency.

Wearable devices enable real-time health monitoring, alerting workers to potential risks and hazards. This proactive approach empowers individuals by providing immediate alerts for excessive

exertion, high temperatures, or exposure to hazardous substances, fostering a safer work environment.

Wearables track vital health metrics, facilitating early detection of health issues. This not only promotes preventive care but also allows for timely intervention, reducing the likelihood of workplace injuries and health-related complications.

Wearable technology can provide insights into ergonomic conditions by analyzing movement patterns and postures. Workers can receive personalized feedback to adjust their movements, reducing strain and enhancing overall physical well-being.

The data collected by wearables can be utilized for educational purposes, raising awareness among workers about the impact of certain tasks or conditions on their health. This knowledge fosters a culture of health-consciousness and empowers workers to make informed decisions.

Wearable technology offers management teams immediate access to data on workers' health metrics and environmental conditions. This allows for quick decision-making and the implementation of preventive measures to mitigate risks and prevent accidents.

Access to real-time data enables better workforce management. Management can allocate tasks more efficiently, considering individual health statuses, and adjust work schedules or duties accordingly to maintain productivity while prioritizing worker health.

Preventing accidents through early risk detection not only reduces potential liabilities but also minimizes downtime due to injuries or health-related issues. This leads to significant cost savings and enhances overall project efficiency.

Wearable technology aids in ensuring compliance with health and safety regulations. Accurate data collection and adherence to safety protocols bolster compliance efforts, reducing legal risks and ensuring regulatory adherence.

The wealth of data collected by wearables can be analyzed to identify trends, patterns, and areas for improvement. This data-driven approach enables evidence-based decision-making, optimizing work conditions and safety protocols for long-term benefits.

The Positive Impact of Implementing This Technology on Safety, Productivity and Overall Well-Being

The implementation of wearable technology in construction holds the promise of a profound and multifaceted impact on safety, productivity, and overall well-being, heralding a new era of innovation and progress within the industry.

Wearable technology serves as a vigilant guardian, continuously monitoring vital health metrics and environmental conditions. This real-time monitoring enables the early detection of potential health hazards, empowering workers and management to proactively address risks. Immediate alerts for high temperatures, excessive exertion, or exposure to hazardous substances facilitate swift interventions, thereby mitigating accidents and injuries.

Real-time data insights gleaned from wearable devices inform the optimization of work conditions. Analysis of worker movements and ergonomic data aids in identifying areas prone to strain or injury. Such insights enable the redesign of work processes or equipment to minimize physical strain, thereby fostering safer and more ergonomic work environments.

Wearable technology not only monitors but also educates. By providing workers with personalized feedback based on their health metrics and movement patterns, it empowers individuals to make informed decisions about their actions and well-being. This education fosters a culture of health-consciousness, reducing risks associated with unawareness or lack of information.

A safer work environment directly correlates with increased productivity. Reduced accidents and injuries minimize work interruptions, ensuring continuity in project timelines. Moreover, the proactive management of worker health prevents fatigue-related errors, enabling workers to maintain focus and efficiency throughout their shifts.

Beyond safety, wearable technology contributes to the overall well-being of workers. Continuous health monitoring enables the detection of early signs of health issues, promoting preventive care and timely interventions. This fosters a healthier workforce, reducing absenteeism due to health-related reasons and improving workers' overall quality of life.

The wealth of data collected by wearables allows for data-driven decision-making at both operational and strategic levels. Management can analyze trends, identify patterns, and make informed decisions to optimize work processes, allocate resources effectively, and refine safety protocols based on empirical evidence.

Implementing wearable technology instigates a cultural shift within the construction industry. Embracing technology to prioritize safety and well-being underscores a commitment to workers' welfare. This transformative shift fosters a culture of continuous improvement, innovation, and a collective dedication to creating safer and healthier work environments.

Potential Future Research Avenues That Could Stem from This Study

The study on the "Use of Wearable Technology in Construction Worker Health Monitoring" lays a sturdy foundation for future research avenues, offering a springboard for deeper exploration and innovation within the construction industry. Several potential directions emerge from this study, propelling further advancements and insights in this field.

Future research could delve into longitudinal studies to assess the long-term health impact of wearable technology on construction workers. Examining health trends over extended periods could provide invaluable insights into the effectiveness of preventive measures and the sustained benefits of continuous health monitoring.

Understanding the behavioral aspects of technology adoption among construction workers becomes crucial. Future research might explore the psychological factors influencing worker acceptance, adherence, and the sustainability of using wearable devices. This includes studying motivations, barriers, and strategies to enhance technology adoption.

Incorporating advanced analytics and artificial intelligence (AI) into wearable technology opens avenues for predictive analytics. Future research could focus on developing AI-driven algorithms capable of predicting potential health risks based on historical data, thereby enabling more proactive risk management.

Collaboration across disciplines such as healthcare, engineering, and data science can lead to more holistic health monitoring systems. Research could explore interdisciplinary approaches to integrate wearable technology with medical databases, enabling more comprehensive health assessments and interventions.

As wearable technology collects sensitive health data, future research should delve deeper into ensuring data privacy, ethical use, and compliance with regulations. Exploring methodologies to anonymize data while preserving its utility becomes imperative to address privacy concerns.

Tailoring wearable devices to suit the diverse needs of construction workers remains a critical area for exploration. Research could focus on designing customizable devices that account for various job roles, environmental conditions, and individual health profiles. Conducting detailed cost-benefit analyses could shed light on the economic viability and return on investment associated with implementing wearable technology. Evaluating the financial impact, including reduced healthcare costs and increased productivity, provides essential insights for industry stakeholders. Research into designing wearable technology with a worker-centric approach is pivotal. Understanding human factors, ergonomics, and user experience can lead to the development of devices that seamlessly integrate into the work environment, ensuring comfort and usability.

Exploring the implementation of wearable technology in construction across diverse geographical regions and cultural contexts offers valuable insights. Understanding how cultural

nuances impact technology adoption and usage patterns can inform strategies for global implementation.

Conclusion

As the study concludes, several key insights emerge, paving the way for transformative changes within the construction industry. Firstly, the integration of wearable technology heralds a paradigm shift in occupational health and safety practices. Continuous monitoring of workers' health metrics in real time offers a proactive approach to risk management, empowering both workers and management to swiftly detect and address potential health hazards. Moreover, the findings underscore the multifaceted benefits of wearable technology. Not only does it contribute to a safer work environment by mitigating risks and preventing accidents, but it also fosters a culture of health-consciousness among workers. The educational aspect of wearable technology empowers individuals to make informed decisions about their actions and well-being. Furthermore, the study emphasizes the potential for data-driven decision-making and optimization of work conditions. The wealth of data collected by wearables provides valuable insights for management, enabling evidence-based decisions that enhance productivity, allocate resources efficiently, and refine safety protocols. However, the research also highlights the importance of addressing challenges associated with technology adoption, including privacy concerns, user acceptance, and cultural considerations. Ethical practices and user-centric design are imperative to ensure the seamless integration of wearable technology into the construction work environment. In conclusion, the study underscores the transformative potential of wearable technology in construction worker health monitoring. It not only augments safety measures but also elevates productivity and overall well-being. The insights gleaned from this research serve as a catalyst for future endeavors, encouraging continued innovation, interdisciplinary collaboration, and a concerted effort toward creating safer, healthier, and more efficient work environments within the construction industry. Ultimately, the study's findings pave the way for a progressive and technologically advanced landscape, wherein the health and safety of construction workers remain paramount.

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