

Strategy for Strengthening OHS Compliance through Smart Wearables in Industry 4.0 Work Environments

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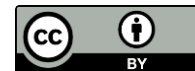
Smart Wearables, Occupational Safety and Health, Worker Compliance, Industry 4.0, Safety Behavior, IoT-based Safety Monitoring

ABSTRACT

The increasing complexity of industrial work environments in the Industry 4.0 era demands more innovative approaches to occupational safety and health (OSH) management, particularly in strengthening worker compliance with safety procedures. This study aims to analyze the effect of the utilization of smart wearable technology on worker compliance with OSH procedures in industrial work environments transitioning toward Industry 4.0. This research employed a quantitative approach with an explanatory research design. Data were collected through structured questionnaires distributed to 125 workers selected via purposive sampling from industrial units with high occupational risk exposure. Data analysis was conducted using simple linear regression, hypothesis testing (t-test), and coefficient of determination (R^2). The results demonstrate that smart wearables utilization has a significant positive effect on worker OSH compliance ($B = 0.712$; $t = 9.365$; $p = 0.000$), with the technology explaining 52.0% of the variance in compliance behavior ($R^2 = 0.520$). These findings confirm that real-time monitoring capabilities, hazard notification systems, and physiological condition tracking embedded in wearable devices serve as key mechanisms in reinforcing safe work behavior. Nevertheless, the remaining 48.0% of variance suggests that organizational safety culture, training quality, and management supervision remain critical complementary factors. Smart wearables should therefore be strategically integrated within a comprehensive OSH management ecosystem to achieve sustainable compliance improvement in the Industry 4.0 context.

INTRODUCTION

The development of digital technology in recent decades has driven a major transformation in industrial production systems, known as the Industry 4.0 revolution. This revolution is characterized by the integration of various digital technologies such as the Internet of Things (IoT), artificial intelligence, big data analytics, and cyber-physical systems, enabling production processes to become more automated, connected, and data-driven. This transformation has not only increased



industrial efficiency and productivity but also transformed the way organizations manage various operational aspects, including occupational safety and health (OHS) (Taifa, 2022).

In the context of Industry 4.0, occupational safety management has shifted from a conventional approach to a digital technology-based safety system known as the Safety 4.0 concept. This concept emphasizes the use of digital technology to improve the effectiveness of occupational safety management systems through real-time monitoring of working conditions, risk data analysis, and data-driven decision-making in controlling potential hazards in industrial environments (Singh et al., 2021).

Despite the implementation of various occupational safety systems across industrial sectors, workplace accidents remain a serious problem both globally and nationally. The International Labour Organization (ILO) reports that millions of workers experience workplace accidents each year, resulting in economic and social losses for companies and communities. In Indonesia, the number of workplace accidents continues to increase annually, necessitating a new, more effective approach to occupational safety management (Widodo, 2021).

The implementation of Occupational Safety and Health (OSH) is a corporate obligation as regulated in Law Number 1 of 1970 concerning Occupational Safety. Therefore, companies need to create a safe working environment and manage human resources optimally so that K3 implementation can run effectively and support the creation of a safe work culture (Basofi & Pendrian, 2025). Occupational health and safety (OHS) also plays a vital role in supporting a company's operational success by creating a safe and healthy work environment. Strengthening the OHS culture is becoming increasingly important in the Industry 4.0 era, particularly to improve worker awareness and compliance with safety procedures and the consistent use of personal protective equipment (Fatliana et al., 2025).

The International Labour Organization (ILO) also emphasizes the importance of a safety culture as an effort to make safety a top priority in the workplace and reduce the risk of occupational accidents (Altruisa & Suseno, 2026). One of the main factors contributing to workplace accidents is unsafe behavior and low worker compliance with safety procedures. Various studies in Indonesia support the assertion that most workplace accidents are caused by human factors, such as non-compliance with safety procedures, in addition to environmental conditions. Human error often dominates, contributing up to 96% of total cases in certain sectors. (Aswad & Ardan, 2025).

Low levels of compliance with occupational safety procedures are often influenced by various factors, such as lack of supervision, low worker awareness of occupational risks, and limitations in the company's safety monitoring system. Manual occupational safety monitoring systems generally rely on periodic inspections by occupational health and safety officers or supervisors, thus failing to continuously monitor worker activities (Utami, Akila Neditha, 2024).

The development of digital technology has indeed driven significant innovation in occupational safety and health (OHS) management, particularly through the integration of IoT, sensors, and data analytics for real-time monitoring. In Indonesia, applications such as PROTEK3 combine AI and IoT for early hazard detection, improving incident response, and effectively reducing corrective time (Suhartina et al., 2025).

A digital technology-based occupational safety approach also supports the implementation of predictive safety management, an approach that utilizes data analysis to identify risk patterns



and predict potential workplace hazards. By leveraging data continuously collected through sensors and digital devices, organizations can develop more proactive occupational safety systems to control the risk of workplace accidents (Singh et al., 2021).

One of the emerging technological innovations supporting occupational safety systems is the use of smart wearable devices. Smart wearables are wearable technological devices equipped with various sensors to monitor workers' physiological condition and the work environment in real time (Svertoka et al., 2021).

Wearable devices in industrial settings can include smart helmets, smart safety vests, smart watches, or body sensors integrated with a company's digital monitoring system. This technology allows for continuous data collection on worker position, fatigue levels, exposure to hazardous environments, and physiological conditions that could potentially impact workplace safety (Svertoka et al., 2021).

In addition to functioning as a workplace safety monitoring tool, wearable technology also has the potential to improve worker compliance with safety procedures. The notification and feedback systems provided by wearable devices can help workers become more aware of potential hazards in the work environment, thereby encouraging safer work behaviors (Singh et al., 2021).

Despite the rapid development of wearable technology in occupational safety, most research still focuses on the development of device technology and sensor systems. Research specifically addressing strategies for implementing wearable technology to improve worker compliance with occupational safety procedures remains relatively limited, particularly in the context of industrial environments transforming toward Industry 4.0 (Svertoka et al., 2021).

Furthermore, integrating wearable technology into a company's OHS management system still faces various challenges, such as organizational readiness, employee acceptance of new technology, and data integration with existing safety management systems. Therefore, a more comprehensive study is needed to understand how wearable technology can be effectively implemented to support improved occupational safety compliance.

Based on these problems, this study aims to examine strategies for strengthening occupational safety and health compliance through the use of smart wearables technology in the Industry 4.0 work environment. This study is expected to provide theoretical contributions in the development of digital technology-based occupational safety management concepts and provide practical recommendations for industries in improving worker compliance with occupational safety procedures through the use of wearable technology.

METHODS

This research employed a quantitative approach with an explanatory research design aimed at analyzing the impact of utilising smart wearables technology on workers' compliance with occupational health and safety (OHS) procedures in an industrial environment transitioning toward Industry 4.0. The explanatory design was chosen because this study specifically tests the causal relationship between the independent and dependent variables through hypothesis testing formulated based on theoretical frameworks and previous empirical research.

The research was conducted in the industrial sector that has implemented an OHS management system and utilized sensor-based digital technology or wearable devices in its

operations. The determination of the research location was conducted purposively, considering the suitability of the work environment characteristics in the context of implementing Industry 4.0-based safety technology. The research process includes the stages of instrument preparation, data collection, data processing and analysis, up to the interpretation of research results.

The research population consists of all workers involved in operational activities in work units with a high level of occupational safety risk. The sampling technique used is purposive sampling with the criteria for respondents being workers directly involved in the operational process, having a minimum work experience of one year, and understanding OHS procedures in the work environment. Based on these criteria, the sample size in this study is 125 workers, which is considered adequate for simple linear regression analysis and inferential hypothesis testing.

The research variables consist of independent and dependent variables. The independent variable is the utilisation of smart wearables technology, operationalized through indicators such as the device's ability to monitor worker conditions in real-time, provide hazard notifications, monitor physiological conditions, detect potential workplace environmental risks, and integrate with the OHS management system. The dependent variable is worker compliance with OHS procedures, measured through indicators such as the use of personal protective equipment (PPE), adherence to safe work procedures, compliance with safety instructions, awareness of work risks, and safe work behavior.

Data collection was conducted through a structured questionnaire with a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure respondents' perceptions of both research variables. To strengthen contextual validity, the data were also supported by field observations related to the implementation of the OHS system and the use of wearable technology in the workplace, as well as secondary data from company documents and relevant scientific literature.

Data analysis was conducted in stages, starting with descriptive statistical analysis to describe the characteristics of the respondents. Next, validity and reliability tests of the instrument were conducted, where validity was tested using item-total correlation and reliability using Cronbach's Alpha coefficient to ensure the internal consistency of the instrument.

To address the research objectives and test the hypothesis, simple linear regression analysis was used to identify the impact of smart wearables utilisation on workers' compliance with occupational health and safety procedures. Hypothesis testing was conducted using a t-test at a significance level of 5% ($\alpha = 0.05$), which directly resulted in the statistical values reported in the research findings ($t = 9.365$; $p = 0.000$), allowing for conclusions regarding the significance of the independent variable's influence on the dependent variable. Additionally, the coefficient of determination (R^2) was used to measure the model's ability to explain variations in worker compliance, which in this study yielded a value of 0.520, as reported in the results section. The entire data analysis process was conducted using statistical software (SPSS software), and the analysis results were interpreted quantitatively to explain the magnitude of the effect ($B = 0.712$), the significance of the relationship, and the contribution of smart wearables in explaining variations in OHS compliance in the context of Industry 4.0-based industries.



RESULTS

1. Respondent Characteristics

Table 1. Characteristics of Research Respondents

Characteristics	Category	Number (n)	Percentage (%)
Gender	Male	92	73.6
	Female	33	26.4
Age	< 25 years	18	14.4
	25–35 years	54	43.2
	36–45 years	38	30.4
	> 45 years	15	12.0
Years of Experience	1–5 years	47	37.6
	6–10 years	42	33.6
	>10 years	36	28.8

The results of the analysis show that the majority of respondents are male workers (73.6%), reflecting the general characteristics of the industrial sector, which is dominated by a male workforce. Most respondents were in the 25–35 age group (43.2%), indicating that the industrial workforce is dominated by the working age-population. Furthermore, most respondents had worked for 1–5 years (37.6%), indicating that workers are still relatively early in their work experience, making the implementation of technology-based occupational safety systems crucial for improving compliance with OHS procedures.

2. Linear Regression Analysis

Table 2. Linear Regression Analysis Results

Variables	Coefficient (B)	t count	Sig.
Constant	1.245	4.112	0.000
Smart Wearables (X)	0.712	9.365	0.000

Regression Equation

$$Y = 1.245 + 0.712X$$

The results of the regression analysis show that the use of smart wearable technology has a positive effect on worker compliance with OHS procedures. The regression coefficient value of 0.712 indicates that every one-unit increase in smart wearable utilization will increase compliance with OHS procedures by 0.712 units.

3. Hypothesis Test (t-Test)

Table 3. t-Test Results

Variables	t count	t table	Sig
Smart Wearables → OHS Compliance	9.365	1.98	0.000

The results of the hypothesis test show that The calculated t value (9.365) is greater than the t table (1.98) with a significance value of $0.000 < 0.05$, so it can be concluded that the use of smart wearable technology has a significant effect on worker compliance with work safety procedures.

4. Coefficient of Determination

Table 4. Coefficient of Determination

Model	R	R Square	Adjusted R Square
Regression	0.721	0.520	0.516

The R Square value of 0.520 indicates that 52% of the variation in worker compliance with work safety procedures can be explained by the use of smart wearables technology, while the remaining 48% is influenced by other factors such as work safety culture, management supervision, OHS training, and worker behavioral factors.

DISCUSSION

1. The Effect of Smart Wearables on OHS Compliance: Results of Linear Regression Analysis

The results of the linear regression analysis presented in Table 2 indicate that the use of smart wearable technology has a positive and significant influence on worker compliance with occupational safety and health (OHS) procedures. The regression equation obtained is $Y = 1.245 + 0.712X$, with a regression coefficient (B) of 0.712 and a significance value of 0.000 (<0.05).

Furthermore, these findings support the Theory of Planned Behavior (TPB) proposed by Ajzen (1991), where the intention to behave safely is influenced by attitudes, subjective norms, and perceived behavioral control. The presence of smart wearable technology that provides real-time feedback and notifications serves as a reinforcement mechanism that shapes workers' positive attitudes toward OHS procedures. This sensor-based monitoring system indirectly increases workers' perceived behavioral control in complying with applicable occupational safety standards.

According to their study "Trends in Workplace Wearable Technologies and Connected-Worker Solutions for Next-Generation Occupational Safety, Health, and Productivity" published in *Advanced Intelligent Systems*, wearable technology with real-time monitoring sensors consistently influences in workplace safety behavior. According to the study, wearable technology's data-driven feedback system can dramatically lower risky behavior in the building, manufacturing, and warehousing industries (Patel et al., 2021).

Similar results were also found by Suryawanshi et al. (2024) in a study entitled 'A Comprehensive Survey on Smart Wearables: Real-time Health and Workplace Monitoring, Alerting, and Analysis in the Industrial Context' published in *IJE Transactions*. The study confirmed that the integration of IoT-based wearable devices with artificial intelligence can improve compliance with PPE use and adherence to safety procedures through responsive early warning mechanisms. Suryawanshi et al. (2024) also noted that worker compliance with safety protocols increased substantially when wearable devices were integrated into a more comprehensive safety management system.

Their study, which was published in the *Ain Shams Engineering Journal*, demonstrated a favourable correlation between adherence to safety regulations and the use of wearable technology in high-risk industrial sectors. The study assessed the efficacy of different wearable device types in supporting occupational safety management systems using a multi-criteria decision-making method and discovered that devices with physiological and work environment monitoring capabilities had the greatest impact on enhancing compliance with OHS procedures (Aksut et al., 2023).



This suggests that the strong influence of smart wearables on OHS compliance, as indicated by the regression coefficient of 0.712, reflects complementary deterrence and enforcement mechanisms. On the one hand, the real-time monitoring function of wearable devices creates a deterrent effect, meaning workers are more likely to comply with OHS procedures because they realize their activities are being continuously monitored. On the other hand, the notification and hazard warning systems provided by wearable devices serve as enforcement mechanisms that actively reinforce compliance behavior.

The researchers also assumed that the relatively strong regression coefficient value (0.712) indicates that smart wearables technology not only plays a role as a passive monitoring tool, but also as an active agent of behavior change in the context of OHS. This indicates the need for strategic investment in developing the capacity of wearable devices that are more adaptive to the local industrial context, considering that the characteristics of workers and the work environment in Indonesia have their own uniqueness compared to the global industrial context.

2. Significance of the Influence of Smart Wearables on OHS Compliance: Hypothesis Test Results

The results of the hypothesis test (t-test) presented in Table 3 show that the calculated t-value for the smart wearables variable of 9.365 is significantly greater than the t-table value of 1.98, with a significance value of 0.000 which is far below the set threshold of 0.05 ($\alpha = 5\%$). Based on the hypothesis testing criteria, this condition confirms the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1), which states that the use of smart wearables technology has a significant effect on worker compliance with OHS procedures.

These findings are also relevant to the Behavior-Based Safety (BBS) theoretical framework, which emphasizes the importance of behavioral measurement and feedback as a key mechanism for improving safety compliance. In the context of BBS, smart wearables serve as data-driven behavioral measurement instruments capable of providing more objective, consistent, and real-time feedback than manual observation. This supports the formation of a positive behavior chain through continuous reinforcement of safe work practices.

The findings of this research hypothesis test are consistent with the results of research conducted by Naranjo et al. (2025) published in the MDPI Sensors journal entitled 'Wearable Sensors in Industrial Ergonomics: Enhancing Safety and Productivity in Industry 4.0'. Through a scoping review of 36 selected studies from more than 1300 articles, Naranjo et al. (2025) confirmed that wearable devices consistently have a significant impact on ergonomic and safety conditions in industrial environments, particularly through the integration of artificial intelligence that enables predictive monitoring of workers' health and safety conditions (Naranjo et al., 2025).

Similar results were reported in the International Journal of Environmental Research and Public Health, who found that the use of smart helmets equipped with telemetry sensors in the construction sector significantly impacted compliance with PPE use. The study used a quasi-experimental approach and found that the group using smart helmets demonstrated a statistically significant higher level of compliance with OHS procedures than the control group using conventional helmets (Kim & Choi, 2022).

The researcher assumes that the very high t-value (9.365) reflects the condition where workers feel the direct utility of smart wearable devices in their daily work activities, especially in terms of awareness of work environment hazards. This assumption is based on the characteristics of the research respondents, most of whom are of productive age (25-35 years) with a working period of 1-5 years, who are demographically a group that is relatively adaptive to new technology (digital natives).

Furthermore, the researchers assume that the very strong significance of the influence of smart wearables on OHS compliance can be influenced by contextual factors, namely the environmental conditions of the industry that implements a relatively structured OHS management system. In the context of an industry with a well-established safety culture, the integration of smart wearables tends to have an amplification effect on the existing safety system, resulting in a very high significance value. The implication of this assumption is that the effectiveness of smart wearables is likely contextual and can vary depending on the maturity of the existing OHS system in the company.

3. Contribution of Smart Wearables Utilization in Explaining OHS Compliance: Coefficient of Determination

The results of the coefficient of determination analysis presented in Table 4 show an R value of 0.721, indicating a strong correlation between the use of smart wearables and worker compliance with OHS procedures. The R Square value of 0.520 means that 52% of the variation in worker compliance with occupational safety procedures can be explained by the variable of smart wearable technology utilization. Meanwhile, the Adjusted R Square value of 0.516 is a more conservative measure after adjusting for the number of predictors in the model, indicating that the model has a good level of feasibility.

The R Square value of 52% obtained in this study reflects the accuracy of the research model in partially explaining the phenomenon of OHS compliance. From the perspective of Technological Determinism Theory, this value indicates that technology plays a significant but not sole determinant role in shaping occupational safety behavior. This finding supports the view that OHS transformation in the Industry 4.0 era is socio-technical in nature, namely the result of the interaction between technological factors and socio-organizational factors, both of which need to be considered simultaneously.

Discovered that between 45 and 60 percent of the diversity in occupational safety behavior across different industrial sectors might be explained by wearable IoT systems with AI capabilities. This range of values is in line with the study's R Square of 0.520, which shows that while a regression model with a single wearable technology predictor has a significant explanatory capacity, it needs to be strengthened with complementary predictors to obtain a more thorough understanding of the factors influencing OHS compliance (Suryawanshi et al., 2024).

According to their thorough analysis of wearable research in industrial environments, wearable technology with AI integration accounted for a larger percentage of occupational safety variation than traditional wearable technology. This suggests that wearable technology's explanatory capacity will grow in tandem with the advancement of the devices' computational



capabilities, which may raise the coefficient of determination in subsequent research of a similar nature (Naranjo et al., 2025).

According to national research, wearable technology, when paired with a thorough OHS management system, can account for over 55% of the variation in occupational safety indicators in high-risk industrial sectors. This result supports the claim that the study's R-square value of 52% is within a respectable range and can be raised by incorporating pertinent mediator and moderator factors, such as organisational preparedness and safety culture (Aksut et al., 2023).

The researcher assumes that the R Square value of 52% reflects the baseline condition of the effectiveness of smart wearables in explaining OHS compliance in an industrial environment that is still relatively in the early phase of adopting wearable technology. This assumption is based on the characteristics of the work period of the research respondents, most of whom are in the range of 1-5 years (37.6%), which indicates that workers are still in the process of adapting to the OHS system based on digital technology in their work environment.

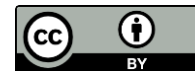
The researchers also assumed that the 48% variance that could not be explained by the model is an important indication of the need for further research that includes contextual variables such as occupational safety culture, the quality of OHS training programs, the level of management supervision, and the compatibility of technology with the specific characteristics of the work environment. This condition opens up opportunities for the development of a more comprehensive model through path analysis or structural equation modeling (SEM) that is able to identify not only the direct influence of smart wearables, but also the mediating and moderating mechanisms that play a role in shaping OHS compliance in the Industry 4.0 era.

The strategic implication of this determination coefficient finding is that the implementation of smart wearables should be viewed as a component of a broader OHS management ecosystem, not as a standalone solution. Industrial organizations investing resources in smart wearable technology need to simultaneously strengthen the non-technological dimensions of their OHS systems, including developing worker OHS competencies, strengthening safety leadership at the supervisory level, and building a safety culture oriented towards proactive prevention.

CONCLUSIONS

This study proves that the use of smart wearables technology has a positive and significant effect on worker compliance with occupational safety and health (OHS) procedures in an industrial environment transforming towards Industry 4.0. The results of the linear regression analysis show an influence coefficient of 0.712 with a significance value of 0.000, which means that every one unit increase in the use of smart wearables is consistently followed by an increase in OHS compliance of 0.712 units. The results of the hypothesis test strengthen these findings through the calculated t value (9.365) which far exceeds the t table (1.98), so that the research hypothesis is accepted at a 99% confidence level. The ability of smart wearables to monitor worker conditions in real-time, provide hazard warning notifications, and integrate safety data into the OHS management system has proven to be a key mechanism that encourages the formation of safer work behavior and compliance with applicable OHS standards.

The coefficient of determination ($R^2 = 0.520$) indicates that smart wearables technology can explain 52% of the variation in workers' OHS compliance, while the remaining 48% is influenced by



factors outside the model, such as organizational safety culture, the quality of OHS training programs, the effectiveness of management supervision, and individual worker behavioral characteristics. This finding confirms that the implementation of smart wearables is an effective strategy but needs to be positioned as part of a comprehensive OHS management ecosystem, not as a single solution. Therefore, industries that are transforming towards Industry 4.0 are advised to integrate smart wearables technology synergistically with strengthening safety culture, empowering workers' OHS competencies, and developing data-driven safety management systems to achieve optimal and sustainable OHS compliance levels.

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