Awareness and adoption of wearable technologies for health and safety management in the Nigerian construction industry

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Abstract

Purpose – Technologies have had a positive impact on the construction industry. Technologies such as BIM, automation, augmented and virtual reality, Internet of Things and robotics have been adopted by construction firms to enhance productivity. However, not much research has been done on the awareness and adoption of wearable technologies for health and safety (H&S) management. This paper investigates the level of awareness and adoption of wearable technologies for H&S management in the Nigerian construction industry.

Design/methodology/approach – A quantitative research method was adopted for the study. An electronic questionnaire format was used as an instrument to collect the data. Both descriptive (mean score) and inferential statistics (Kruskal–Wallis test) were used to analyse the data.

Findings – The results indicate that organisations rarely use H&S wearable devices for H&S management although professionals within the construction industry are somewhat aware of the common H&S wearable devices. The findings further indicate that all 11 variables were perceived as "rarely adopted", whereas 2 variables were perceived as "aware", 3 variables as "slightly aware" and the remaining 6 variables as "somewhat aware".

Research limitations/implications – Data were collected from only construction professionals working in government agencies, consultancy firms and grade D contracting firms in Lagos and Abuja. For a broader perspective, a study that expands the number of states and categories of construction firms is recommended.

Practical implications – The construction industry in Nigeria can use the recommendations to improve H&S management on site. Moreover, the recommendations can contribute to the development of policies to promote the adoption of wearable technologies in construction sites.

Originality/value – Research on wearable technologies, particularly in the Nigerian construction industry, is at the developing stage. With this article, the authors contribute to the body of knowledge in this area of research.

Keywords Adoption, Awareness, Construction, Health and safety, Nigeria, Wearable technology

Paper type Research paper

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Introduction

The construction industry in every country plays a key role towards economic development. It provides the necessary facilities and infrastructure needed for other sectors' development. The construction industry contributes to about 7% of the global job creation and 10% of global Gross Domestic Product (GDP) (Djokoto *et al.*, 2014). With specific reference to Nigeria, Ogunsanya *et al.* (2019) indicated that the construction industry contributes to the economy by employing over 6 million people. Moreover, Abubakar *et al.* (2018) revealed that the construction sector makes a 3.8% contribution to the Nigerian GDP. Notwithstanding the significant contributions to employment and the GDP of a country, the construction industry's health and safety (H&S) outlook is generally negative. For example, ILO (2017) revealed that the construction industry accounts for about one-sixth of the 313 million global annual injuries. Several studies conducted across the globe highlight the inherent risk and negative outlook of the construction industry (e.g. Legg *et al.*, 2015; Okoro *et al.*, 2022; Maiti and Choi, 2019). This situation is not different in Nigeria. For example, Umeokafor (2020) revealed that effective implementation of H&S legislation, standards and measures is lacking in Nigeria. Other studies conducted by Kukoyi and Smallwood (2017), Ibrahim *et al.* (2018) and Umeokafor (2020) provide evidence of construction H&S management challenges/lapses in Nigeria.

The nature of construction and the activities involved such as manual handling (e.g. lifting weights), material handling (e.g. working with dangerous materials and pollutants), working around plants, working at height and working in/with awkward postures make construction hazardous and risky (Antwi-Afari *et al.*, 2017; Haslam *et al.*, 2005; Dutta *et al.*, 2020). Apart from the nature of work, several other factors such as suitability and condition of materials, shortcomings with equipment and tools, and workplace issues also contribute to construction H&S problems (Haslam *et al.*, 2005). Moreover, insufficient supervision, H&S management inadequacy, and poor H&S training contribute to construction H&S problems (CIDB, 2009). To mitigate the negative outlook of construction and the level of accidents on site, effective measures need to be implemented. Pollitt (2006) is of the opinion that instituting effective training and awareness creation systems can help improve H&S management on site. Furtherance to awareness creation among contractors and employees, Vitharana *et al.* (2015) revealed that educating workers on risk factors and risk prevention can also help to improve safety on site. Moreover, the application/adoption of technologies could help to mitigate these H&S challenges. Notwithstanding, the majority of studies on construction H&S have focused on policy, management approaches, and human and cultural aspects of safety (Williams *et al.*, 2020), with less attention on the application of technologies in H&S management (Awolusi *et al.*, 2018). In the African context, little research has been carried out on the application of technologies for H&S management. To buttress, Aghimien *et al.* (2019) indicated that countries in Africa have less research focus on the application of digital technologies in the construction industry. The few studies conducted in Africa include Afolabi *et al.* (2019), Moshood *et al.* (2020), Oke and Arowoiya (2021), Agyekum *et al.* (2022) and Ejidike *et al.* (2022). Wearable safety devices, geographic information systems, sensing technologies, virtual reality and BIM are the main technologies currently adopted for H&S management in Africa (Agyekum *et al.*, 2022). This demonstrates that wearable devices are one of the important H&S technologies adopted in the construction industry. With regard to wearable devices, there is no evidence of studies conducted in sub-Saharan Africa to determine the extent of their adoption for H&S management. The study of Afolabi *et al.* (2019) focused on e-Procurement technologies in Nigeria whilst Moshood *et al.* (2020) determined, "barriers and benefits of ICT adoption in the Nigerian construction industry: A comprehensive literature review". Moreover, the focus of Oke and Arowoiya's study was on augmented reality technology in the construction industry (Oke and Arowoiya, 2021). It is on this premise that this paper seeks to investigate the level of awareness and adoption of wearable technology for H&S management in the Nigerian construction industry.

Overview of construction health and safety in Nigeria

The unsatisfactory state of construction H&S management in Nigeria can be attributed to a number of factors. For example, Umeokafor (2018) revealed that the H&S regulatory system in Nigeria is fragmented, and that compliance with H&S laws is very low. Also, construction firms in Nigeria allocate few resources to H&S management and rarely keep on-site accident and injury records (Ikechukwu *et al.*, 2013). Moreover, there is lack of specification of the client roles and responsibilities in the H&S regulation leading to a low level of client involvement (Umeokafor, 2017). As a result of these lapses, researchers have proposed several interventions to improve construction H&S in Nigeria. Okoye (2016) proposed construction H&S performance improvement frameworks whereas Okoye *et al.* (2017) developed H&S intervention strategies for the industry. Although the recommendations from the existing studies are steps in the right direction, there is still much to be done to improve H&S in the Nigerian construction industry. Umeokafor (2018) revealed that H&S studies conducted in Nigeria do not focus on issues that can have significant improvement in H&S management such as designing out hazards and building information modelling and advanced technology. Construction H&S studies in Nigeria have generally focused on occupational hazards, risk assessment and control, and risk management and techniques. Some studies have focused on the general practice of safety management and accident prevention, whilst a few other studies address H&S regulations and compliance (e.g. Kukoyi and Adebowale, 2021; Umeokafor, 2018; and Umeokafor, 2020). Whereas advanced technologies could improve construction H&S on site, little research has been done on the use of technologies to promote construction H&S management. Smart practices have proven to have some advantages over traditional H&S programmes in terms of accidents and fatalities prevention in construction workplaces (Okoye *et al.*, 2017). One of the technologies that can be adopted to promote H&S management is wearable devices.

Wearable technologies for health and safety management

Wearable technologies have applications across many industries and/or fields; they are widely used in the medical and health fields, sports, mining, military, education and infotainment (Awolusi *et al.*, 2018). Seneviratne *et al.* (2017) defined wearable devices as wearable computer devices that are controlled by, and can interact with, the user. These devices are generally incorporated into clothing and accessories of the wearer (Sultan, 2015). Characteristics of wearable devices are wearability, portability and intelligence (Cheng *et al.*, 2021). Cheng *et al.* (2021) indicated that wearable devices are undergoing rapid development due to their ability to perform functions on the user's body. Thus, wearable devices have broad applications across many fields including the construction industry (Awolusi *et al.*, 2018). Mardonova and Choi (2018) conducted a review of wearable technologies and their applications to the mining industry. The authors classified the wearable devices into smartwatch, smart eyewear, fitness tracker, smart clothing, smart camera and wearable medical device. Awolusi *et al.* (2018) classified sensors for wearable devices applicable for construction H&S as physiological monitoring, environmental sensing, proximity detection and location tracking. Nnaji *et al.* (2021) identified smartphone, smartwatch, smart band, smart ring, smart bracelet, smart necklace, smart safety hard hats, smart safety vests, smart safety glasses, smart safety boots, wearable lights, attachable devices and wearable cameras as the main wearable devices used in construction projects in the United States of America. Nnaji *et al.* (2021) further revealed that the most popular wearable devices are smartphone and safety hard hats, followed by smart safety vests, smart safety glasses, wearable lights and attachable devices. Agyekum *et al.* (2022) revealed that the common wearable devices adopted for H&S in the Ghanaian construction industry are safety hats, vests and glasses. Ahn *et al.* (2019) noted that wearable technologies are used in the construction industry for risk recognition, to avoid musculoskeletal disorders of workers, keep watch on workers' mental health status, guide against falls during work, and evaluate workload and fatigue levels of workers. The common wearable devices applicable for construction H&S management are discussed in Table S1.

Awareness and adoption of wearable technologies

Several frameworks and models such as Technology Acceptance Model, Theory of Planned Behavior, Diffusion of Innovation theory, Theory of Reasoned Action, Model of PC Utilisation, Motivational Model, Unified Theory of Acceptance and Use of Technology and Social Cognitive Theory are used to explain user adoption of new technologies (Taherdoost, 2018). Adoption theory examines the individual and the choices an individual makes to accept or reject a particular innovation (Straub, 2009). Rogers (2003) enumerated five stages of the adoption process:

(1) Awareness – Awareness of the innovation, but lacking complete information about it.

(2) Interest – Growing interest and information seeking.

(3) Evaluation – Decision whether or not to try innovation based on present and future situations (process may end here if negative decision).

(4) Trial – Making use of the innovation. (If use does not continue, this is called "reneging" on adoption.)

(5) Adoption – Continued full use of the innovation.

Awareness is the first stage of the process. Straub (2009) believes that a very high awareness rate is a good condition, though not sufficient, for making an informed adoption decision. The authors further indicated that 100% awareness rate is needed to promote adoption. Creating awareness of the advantages of innovative technologies and providing evidence of successes achieved help to counter resistance and thereby promote the adoption of innovative technologies (Arabshahi *et al.*, 2022). However, after awareness is created, further steps – such as education and research – must be taken to ensure effective adoption. Information dissemination resulting from research on the application of technologies helps to promote the uptake of technologies. The few studies on the awareness of technologies in the construction industry demonstrate that the technological awareness level is low in developing countries such as Nigeria (Martınez-Aires *et al.*, 2018). A study by Afolabi *et al.* (2019) and Moshood *et al.* (2020) indicated that the level of awareness regarding the benefits to be derived from the adoption of technology is still low in Nigeria.

With regard to the adoption of technologies, studies suggest that the construction industry is behind the other industries. For example, Agyekum *et al.* (2022) found that the level of usage of technologies for H&S management among construction professionals in Ghana is moderate. Similarly, Arabshahi *et al.* (2022) stated that despite the potential of sensing technology on construction performance, its adoption in construction projects is slow. The authors further revealed that even the popular technologies are not adopted by many construction companies. Nnaji *et al.* (2021) revealed that not all the common wearable devices are adopted for H&S risk mitigation in the United States of America, a country where technology is advanced. The authors further revealed that the most common wearable devices used in construction projects are smartphones, smart hard hats and smart vests. This worrying trend is even worse in developing countries such as Nigeria. Oke and Arowoiya (2021) noted that the adoption of technologies in the Nigerian construction industry is still in a nascent stage. Similarly, Ejidike *et al.* (2022) found that professionals in the Nigerian construction industry are aware of the inherent advantages of using technologies; however, they rarely adopt technologies that could enhance performance.

Research methodology

This study sought to analyse the level of awareness and adoption of wearable technology for H&S management in the Nigerian construction industry. In doing so, deductive reasoning was adopted. This approach enables researchers to move from a generally accepted theory to a specific conclusion (Babbie, 2013). The majority of positivist studies are quantitative in nature. Positivists argue that objective, observable and verifiable facts are the only means of understanding and explaining a phenomenon. In line with the philosophy and approach, quantitative data was collected. Therefore, a quantitative approach using a positivist viewpoint was adopted for this study.

The research population comprised active construction industry professionals – e.g. Architects, Builders, Engineers, H&S officers and Quantity Surveyors – employed by government agencies, consultancy firms and grade A contracting firms. Sampling is the process of selecting a subset of a population to represent the entire population of interest. Accordingly, sampling helps to extract acceptable respondents to represent the larger population from whom data is collected (Welman *et al.*, 2005). Probability and non-probability are the two main methods of sampling. Purposive sampling, a type of non-probability sampling technique, was adopted. Purposive sampling enables the researcher to identify people who have the knowledge or experience to take part in a study. Construction organisations are classified into into grades A, B, C and D based on the organisations' capacity to execute projects. Category D are firms with the capacity to bid for projects between N250m and N1bn. Wearable safety technologies are relatively new to developing countries; consequently, only big construction firms (i.e. grade D), government agencies and consultancy firms were targeted for the study. These categories of firms were selected because they have the financial strength and resources to invest in technologies. Thus, only construction professionals working in government agencies, consultancy firms and grade D firms in Nigeria (i.e. Lagos and Abuja) were included in the study. For data collection, an electronic questionnaire format was used, where a survey link was generated and sent to multiple construction professionals' social media platforms. The survey was open from 15 May 2022 through 4 September 2022. A total of 120 questionnaires were received; however, 12 were not fully completed. Therefore, 108 representing 90% were used for the analysis.

The questionnaire was divided into three sections: demographics, awareness and adoption. The awareness section of the questionnaire was captured on a 4-point Likert scale where 1 = not aware; 2 = slightly aware; 3 = somewhat aware and 4 = aware, whilst the questions for the adoption were captured on a 5-point Likert scale where 1 = never; 2 = rarely; 3 = sometimes; 4 = often and 5 = always. A Mean Score (MS) value range was determined to ensure consistent classification and interpretations. For the 4-point scale, 1 was subtracted from 4 which equals 3, after that, the 3 was divided by 4 equalling 0.75 which becomes the MS range. Consequently, the MS range for "not aware" becomes $>1.00 \leq 1.75$; "slightly aware" becomes $>1.75 \leq 2.50$; "somewhat aware" becomes $>2.50 \leq 3.25$ and "aware" becomes $>3.25 \leq 4.00$. With regard to the 5-point scale, 1 was subtracted from 5 which equals 4, after that, the 4 was divided by 5 equalling 0.8 which becomes the MS range. Consequently, the MS range for "never" becomes $>1.00 \leq 1.80$; "rarely" becomes $>1.80 \leq 2.60$; "sometimes" becomes $>2.60 \leq 3.40$; "often" becomes $>3.40 \leq 4.20$ and "always" becomes $>4.20 \leq 5.00$. This approach was also adopted by Adebowale (2018) and Simpeh and Adisa (2021).

Before data gathering, the research questionnaire was vetted by senior industry practitioners. The feedback received helped to improve the questionnaire. To ensure the reliability of the research, the questionnaire was tested with Cronbach's alpha value. Ursachi *et al.* (2015) clarified that whilst a value of 0.8 or greater Cronbach's alpha value is considered very good, a value of 0.6–0.7 indicates an acceptable level of reliability. The Cronbach's alpha coefficient value obtained for the awareness was 0.843 whereas 0.959 was obtained for the adoption. This demonstrates that the questions on the questionnaire were reliable.

Both descriptive (i.e. Mean Score) and inferential (Kruskal–Wallis test) statistics were used to analyse the data. The MS helped to present the data in a meaningful and understandable way, thereby simplifying the interpretation of the data. The Kruskal–Wallis test was used to measure/determine whether there are significant differences in the responses obtained from the different employer type. The p-values were set at 5% ($p < 0.05$), this implies that there is a significant difference in the responses from the different employer type if the value is below 0.05.

Analysis and discussion

Profile of respondent

The demographic information of the respondents indicates that whereas 15% of the respondents were Female, 85% were Male. Thus, majority of the respondents were male. This is anticipated because construction, particularly, in sub-Saharan Africa is male-dominated. Regarding the profession of the respondents, Builders had the highest percentage of 40.7%, followed by Quantity Surveyors with 37.0%. Next was the Architect with 11.1%, H&S officers with 5.6 and Engineers with 1.9%, while others make up the remaining 3.7%. In total, 44% of the employees were from Government Agency, 37% from Contracting and 19% from Consultancy. With regard to the level of education, B.Sc./B.Tech had the highest percentage of 41% whereas HND recorded the lowest (i.e. 9%). The qualification and wide-ranged professional representation indicate that the respondents were best positioned to provide valid responses. See Table S2.

Level of awareness of wearable safety devices in the construction industry

Table 1 shows the respondent's views regarding their level of awareness of wearable safety devices in the construction industry. The Mean Item Score (MIS) is adopted to rank the level of awareness, whilst the Kruskal–Wallis test (non-parametric test) is used to determine whether there are significant differences in the groups (i.e. employee type).

Government agencies had the highest awareness MIS, followed by Consultancy firms, and finally Contracting firms. Respondents from Government agencies ranked Smartwatch (3.46) and Wearable camera (3.46) first, followed by Fitness tracker (3.17). Those from Consultancy firms ranked Smartwatch (3.30) first, followed by Smart bracelet/band (3.10), and Wearable camera (2.90), Smart eyewear (2.90) and Sensor-equipped safety vest (2.90) in third position. With regard to Contracting firms, Smartwatch (3.41) was ranked first, followed by Wearable camera (3.22) and Smart bracelet/band (3.02). All the three employee types ranked Smartwatch as the first wearable safety device whereas Dust sensor, Rain sensor and Sensor incorporated into footwear were all ranked in the bottom three. Moreover, the MIS demonstrate that all the three employee types are aware of Smartwatch as a wearable safety device.

With regard to the combined responses, Smartwatch was ranked first with an MIS of 3.41, followed by Wearable camera with an MIS of 3.22, whereas Sensor incorporated into footwear was ranked last with an MIS of 2.22. The MS range obtained demonstrates that participants are "aware" of Smartwatch and Wearable camera as wearable safety devices. Sensor-equipped safety vest, Smart eyewear, Sensor-equipped safety helmet, Smart bracelet/band, Fitness tracker, Wearable camera and Wearable medical device all obtained MISs between 2.50 and 3.25, demonstrating that respondents are "somewhat aware" of these devices. The last three (Dust sensor, Rain sensor and Sensor incorporated into footwear) were all in the range of "slightly aware". None of the wearable devices was rated below 1.75. This implies that none of the devices was rated as "not aware".

Table 1. Level of awareness of wearable safety devices in the construction industry

	Employer type									
	Government agencies		Consultancy firms		Contracting firms		Total		Kruskal–Wallis	Asymp. Sig
Variables	MIS	RK	MIS	RK	MIS	RK	MIS	RK		
Sensor-equipped safety vest	2.92	7	2.90	3	2.25	7	2.67	7	7.429	0.024*
Smart eyewear	3.08	4	2.90	3	2.70	5	2.91	5	3.284	0.194
Sensor-equipped safety helmet	2.79	8	2.80	6	2.20	8	2.57	8	5.736	0.057
Smartwatch	3.46	1	3.30	1	3.40	1	3.41	1	2.031	0.362
Smart bracelet/band	3.04	5	3.10	2	2.95	3	3.02	3	0.987	0.610
Fitness tracker	3.17	3	2.80	6	2.90	4	3.00	4	1.393	0.498
Wearable camera	3.46	1	2.90	3	3.10	2	3.22	2	5.398	0.067
Wearable medical device	3.04	5	2.70	8	2.40	6	2.74	6	6.251	0.044*
Dust sensor	2.54	11	2.40	9	2.10	9	2.35	9	3.611	0.164
Rain sensor	2.67	10	2.30	10	1.90	10	2.31	10	10.161	0.006*
Sensor incorporated into footwear	2.75	9	2.20	11	1.60	11	2.22	11	21.485	0.000*

Source(s): Table by authors

The Kruskal–Wallis test between employer types shows that the p-values obtained for seven of the variables (i.e. Smart eyewear, Sensor-equipped safety helmet, Smartwatch, Smart bracelet/band, Fitness tracker, Wearable camera and Dust sensor) were above 0.05. This demonstrates that there are no significant differences in the responses from the different employer type. However, Sensor-equipped safety vest, Wearable medical device, Rain sensor and Sensor incorporated into footwear obtained p-values below 0.05, implying significant differences in the responses.

Adoption level of wearable safety devices. The respondent's views on the adoption of wearable safety devices are presented in Table 2. Respondents from Government agencies ranked Fitness tracker (2.83) as the most adopted smart device, followed by Smartwatch (2.71) in the second position, and Smart bracelet/band (2.50) in the third position. With regard to Consultancy firms, Sensor-equipped safety vest (2.60) was ranked first, followed by Sensor-equipped safety helmet (2.40) and Fitness tracker (2.30). Those from Contracting firms ranked Smartwatch (2.10) first, followed by Fitness tracker (1.80) in second position and Smart eyewear (1.75) in third position. It is important to highlight that the three highest ranked wearable devices (i.e. Fitness tracker, Smartwatch and Sensor-equipped safety vest) across all the three employee types were in the range of "sometimes" adopted. Thus, none of the wearable devices was in the range of "often" or "always" adopted. Moreover, it is evident from Table 2 that Government agencies had the highest adoption MIS, followed by Consultancy firms, and Contracting firms in third position. Additionally, the MISs for the Contracting firms demonstrate that 9 out of the 11 variables were rated as "never" adopted.

For the combined responses, Smartwatch was ranked first with an MIS of 2.39 and the second in rank was Fitness tracker with an MIS of 2.35. Sensor-equipped safety vest was third in rank with an MIS of 2.11, the next ranked factor was Sensor-equipped safety helmet having an MIS of 2.09. Rain sensor and Sensor incorporated into footwear were the least ranked with MIS of 1.83. The MS range demonstrates that all the wearable devices obtained MISs between 1.80 and 2.60, demonstrating that all the wearable devices are "rarely" adopted in the Nigerian construction industry.

The Kruskal–Wallis test reveals that there are no significant differences in 6 of the 11 variables. These 6 variables (Sensor-equipped safety vest, Smart bracelet/band, Fitness tracker, Dust sensor, Rain sensor and Sensor incorporated into footwear) had a p-value below 0.05. The other 5 out of the 11 variables all recorded p-values above 0.05. Although five variables recorded significant differences, it is important to state that, with the exception of smartwatch, all these variables were either rated as "rarely" or "never" adopted by all the three employer types.

Awareness versus adoption

The awareness versus adoption ratings show that whereas all 11 variables were perceived as "rarely adopted", only 2 variables were perceived as "aware", 3 variables as "slightly aware" and the remaining 6 variables as "somewhat aware". It is evident that the level of awareness is comparatively higher than the adoption rate (see Table S3). This implies that as much as the participants are generally "somewhat aware" of the common H&S-related wearable devices, their organisation "rarely" use them for H&S management.

Discussion and implications

The MS range obtained reveals that the awareness level of the wearable devices for H&S management was in three categories – "aware", "somewhat aware" and "slightly aware". Two technologies (i.e. Smartwatch and Wearable camera) were classified as "aware", 3 technologies

Table 2. Adoption level of wearable safety devices

Variables	Employer type Government agencies MIS	RK	Consultancy firms MIS	RK	Contracting firms MIS	RK	Total MIS	RK	Kruskal–Wallis	Asymp. Sig
Sensor-equipped safety vest	2.38	4	2.60	1	1.55	8	2.11	3	10.452	0.005*
Smart eyewear	2.29	8	2.00	6	1.75	3	2.04	6	3.091	0.213
Sensor-equipped safety helmet	2.33	5	2.40	2	1.65	5	2.09	4	3.885	0.143
Smartwatch	2.71	2	2.20	4	2.10	1	2.39	1	5.568	0.062
Smart bracelet/band	2.50	3	1.90	7	1.65	6	2.07	5	10.658	0.005*
Fitness tracker	2.83	1	2.30	3	1.80	2	2.35	2	13.225	0.001*
Wearable camera	2.25	9	1.70	11	1.70	4	1.94	9	3.717	0.156
Wearable medical device	2.33	6	1.80	9	1.65	7	1.98	7	4.448	0.108
Dust sensor	2.25	10	2.20	5	1.50	9	1.96	8	8.489	0.014*
Rain sensor	2.33	7	1.80	10	1.25	11	1.83	10	17.465	0.000*
Sensor incorporated into footwear	2.21	11	1.90	8	1.35	10	1.83	10	10.328	0.006*

Source(s): Table by authors

(i.e. Dust sensor, Rain sensor and Sensor incorporated into footwear) as "slightly aware", and 6 technologies (Sensor-equipped safety vest, Smart eyewear, Sensor-equipped safety helmet, Smart bracelet/band, Fitness tracker, Wearable camera and Wearable medical device) as "somewhat aware". With the exception of Smartwatch and Wearable camera which received high awareness rating, respondents were not fully aware of all the other technologies. Straub (2009) believes that a 100% awareness rate is needed to promote adoption. Unfortunately, the findings reveal that professionals in the Nigerian construction industry have just a moderate awareness level of wearable devices for H&S management. The findings collaborate with the studies of Aghimien *et al.* (2019) and Akinlolu *et al.* (2020), who revealed that the awareness of technologies in the construction industry is low in Africa. Moreover, the result is consistent with the finding of Okoro *et al.* (2022) who opined that there is low awareness with regard to technologies that could enhance H&S practices in South Africa. From the Nigerian point of view, Umeokafor (2018) revealed that H&S studies conducted in Nigeria focus less on technology. Similarly, Afolabi *et al.* (2019) and Moshood *et al.* (2020) also found that the level of awareness of the benefits associated with the adoption of technology in the Nigerian construction industry is low.

This implies that continuous awareness creation and education on the emerging trends in H&S management and the advantages/benefits of adopting innovative technologies in H&S management is paramount. Pollitt (2006) posited that effective training and awareness creation systems help to improve H&S management on site. There is a need for construction firms, particularly the big firms, government agencies and consultancy firms to make conscious efforts by setting up a research unit within their firms and/or partnering with research and higher learning institutions to engage in innovative/technological researches. The government and other construction industry stakeholders also have a responsibility to provide financial support to promote research into these areas and further use their platforms to disseminate the findings of such studies. Seminars, special conferences and sensitisation drives should also be organised by construction industry stakeholders to drive this agenda. By so doing, construction firms and the construction industry professionals will become aware and will be willing to accept and adopt these technologies.

With regard to the adoption, all 11 technologies were perceived as "rarely adopted". This finding correlates with those of Akram *et al.* (2019) and Akinlolu *et al.* (2020). Arabshahi *et al.* (2022) similarly found that technological devices are rarely adopted in the construction industry. Another study conducted by Agyekum *et al.* (2022) demonstrates that the adoption level of technologies in sub-Saharan Africa is very low. With specific reference to wearable devices, Nnaji *et al.* (2021) revealed that not all the common wearable devices are adopted for H&S risk mitigation in the United States of America. Studies suggest that countries from Americas, Europe, Australia and Asia are the most technologically innovative in the world (Martınez-Aires *et al.*, 2018; Institute of Management, 2018). Therefore, the findings are not particularly surprising because the general uptake and application of technologies in most of the countries on the African continent is low. With specific references to the Nigerian construction industry, Ejidike *et al.* (2022) revealed that construction firms and professionals in Nigeria rarely adopt technologies.

This implies that after awareness is created, the construction firms, government agencies and consultancy firms have a responsibility to promote the acceptance of these new technologies and develop an organisational culture that embraces change. Moreover, organisations must devise strategies to break the resistance to change. This is crucial because adoption can only thrive if firms develop a culture that embraces change. The number of H&S professionals who responded to the questionnaire is quite low. This implies that the construction industry must put in more effort to promote H&S as a profession in the country.

Conclusion

Organisations have become aware of the important role technologies play in promoting the efficiency of activities. Several technologies such as building information modelling, automation and robotics have been adopted by construction firms to enhance productivity. Wearable technologies are now adopted to enhance construction H&S management. The study reported in this paper investigated the level of awareness and adoption of wearable technology for H&S management in the Nigerian (Abuja and Lagos) construction industry. The findings reveal that all 11 variables were perceived as “rarely adopted”, whereas 2 variables were perceived as “aware”, 3 variables as “slightly aware” and the remaining 6 variables as “somewhat aware”. Although some variables recorded significant differences, the differences recorded were not important since all those variables were either rated as “rarely” or “never” adopted by all the three employer types. It is, therefore, concluded that organisations “rarely” use wearable devices for H&S management although professionals within the construction industry are somewhat aware of the common H&S wearable devices. Only construction professionals working in government agencies, consultancy firms, and grade D contracting firms in Lagos and Abuja were used in this study; therefore, the findings of the study may not be generalised beyond this group. A study that expands the number of participating firms is, thus, recommended. The adoption level recorded is very low; therefore, it is recommended that construction/consultancy firms and government agencies commit more financial resources to promote the acceptance and procure these devices to promote H&S management on construction sites. All stakeholders in the construction industry have a responsibility to campaign for the adoption of H&S wearable devices by emphasising their importance and benefits. Research on wearable technologies, in developing countries, is very low. Therefore, this study contributes to the body of knowledge in this evolving area of research.

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Supplementary table

The supplementary material for this article can be found online.

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