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Evaluating the effectiveness of strategies for mitigating fatigue among construction workers in Abuja, Nigeria: a quantitative analysis

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ABSTRACT

Fatigue is one of the menaces that contribute to the rising number of construction-related accidents and fatalities in projects. Therefore, the purpose of this study is to identify several strategies that can be adopted to mitigate fatigue in construction projects. This was achieved through a quantitative study. A questionnaire was the main instrument for data collection in the quantitative study. The study revealed that frustration/depression or work pressure is one of the significant causes of fatigue in construction projects. Fatigue risk management education and bonding among workers are some of the underlying strategies that can be used to mitigate the identified causes. Depending on the nature of the fatigue causative elements, the study further established that some mitigation strategies are more effective than others. Therefore, further studies should be conducted by prospective researchers on a range of attributes that may influence the success of fatigue mitigation strategies in construction projects.

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accidents; construction worker; fatigue; mitigation strategies

1. Introduction

Construction work involves physically demanding tasks often performed under harsh conditions, resulting in worker fatigue which in turn leads to poor judgement, poor quality of work, increased risk of accidents and reduction in productivity [1,2]. According to Emuze [3] a fatigued person will be less alert, less able to process information and slow to react to events. Therefore, fatigue can be described as contributing to an increased incidence of human errors [4]. Human error is described as 'an inappropriate human decision or behaviour that reduces either quality or safety (or both) during construction operations and thus, deteriorates a project's cost and schedule performance' [5]. These errors have been categorized into physical errors (causing an incident that a person did not mean to cause) and mental errors (doing something wrong while believing it is the right thing to do) [6]. To understand the connection between fatigue and human error, it is essential to observe the effects of mental fatigue and muscular fatigue on human error [1].

Construction workers are prone to carrying out site activities under a fatigued status with poor cognitive conditions, resulting in slowed reaction time, reduced vigilance, reduced decision-making ability, task distraction and loss of situational awareness [7]. Considering the severity of the consequences of fatigue-induced human error on construction project performance [8], the need for the prevention and minimization of these errors within these contexts has been elucidated [5]. Accordingly, minimizing human error remains key to improving safety performance on construction projects [9,10]. Therefore, the mitigation of fatigue among construction workers remains critical to minimizing the incidence of human error and, by extension, safety performance of construction projects [11,12].

Whilst extant literature is replete with studies identifying several strategies developed for achieving effective mitigation of fatigue on construction projects [9,12], literature seeking to evaluate the effectiveness of these strategies within the developing country context remains scant. Acknowledging the paucity of studies seeking to assess the effectiveness of various fatigue mitigation strategies [12–15] reiterated the relevance of knowing the right mitigation strategy to deploy in preventing fatigue causative factors. This study set out to contribute towards achieving this objective, commencing with an identification of the fatigue causative factors and the determination of relevant strategies which can be deployed towards mitigating the incidence of such factors, thereby forestalling an increase in the number of workers experiencing fatigue across construction sites in Abuja, Nigeria. In other words, this study contributes towards bridging this study knowledge gap by drawing from the perceptions of relevant actors within the Nigerian construction industry to evaluate the effectiveness of strategies for mitigating fatigue among construction workers. Based on the afore-stated aim, this study intends to answer two distinct questions:

- What are the causes of fatigue among Abuja construction workers?
- What is the effectiveness of the strategies deployed for mitigating fatigue in Abuja construction projects?

The study specific objectives are as follows:

- to investigate the causes of fatigue among construction workers in Abuja, Nigeria;
- to evaluate the effectiveness of the strategies deployed for mitigating fatigue in Abuja construction projects.

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The rest of this article is structured as follows. Section 2 comprises a synthesis of relevant literature pertaining to understanding the concept of fatigue in construction project/industry contexts, causes of fatigue among workers and an elicitation of fatigue mitigation strategies. Section 3 provides a justification of the research methods adopted for data collection and analysis, whereas the results from the data collection and analysis exercise are presented in Section 4. Section 5 details a comprehensive discussion of the study's results. The implications of the study's results and the conclusions drawn are presented in Section 6.

2. Literature review

2.1. Managing fatigue in construction projects

The term 'fatigue' has been used to refer to loss of efficiency or disinclination towards any kind of effort [2,16]. It can also be described as a state of mental and physical fatigue that interferes with actual task performance [3,17]. Mental weariness, e.g., can be traced back to lengthy periods of cognitive effort and results in a decline in cognitive and behavioural function [2]. Physical weariness, on the other hand, is caused by activities that demand physical exertion and is characterized as a decline in one's ability to conduct physical work [2]. Physically demanding tasks are typical during the construction phase. Intensive working conditions render workers prone to physical fatigue, along with poor judgement of the dynamic construction environment and involved hazards [7]. As a result, it may be inferred that mental exhaustion reduces physical performance in workers [18]. Light physical activity, on the other hand, appears to boost mental performance while high physical exertion degrades mental performance, implying a complex relationship between physical and mental weariness [2].

It is critical to study the impact of mental and bodily exhaustion on human error to better understand the link between fatigue and adherence to a safe working procedure [1]. According to Reason [6], human errors are produced by mental function inadequacies that worsen as mental and physical weariness increase. Organizational factors, local workplace conditions and people's risky acts can weaken a system's protections, resulting in negative results, according to studies on accident causation [6]. According to Hallowell [19], the incidence and severity of injury increased during overtime construction work due to an increase in human error caused by exhaustion in cognitive processes (mental fatigue). Summarily, Fang et al. [1] discovered a linear link between fatigue levels and human errors particularly when workers pay little attention to their workload.

2.2. Causes of fatigue in construction projects

The literature shows that fatigue-induced errors on construction sites are caused by a multiplicity of causes. Table 1 presents the 20 factors identified in the corpus of relevant literature as contributing to the incidence of fatigue amongst construction workers.

Table 1. Causes of fatigue.

Cause of fatigue-induced human errors	Source
Lack of orderliness among workers	[20–22]
Excessive workloads that employees cannot cope with	[14,23]
Frustration/depression or work pressure	[24–26]
Awkward working postures	[14]
Poor communication among workers	[8,16,27]
Unexpected challenges or unforeseen situation in the construction process	[14,23]
Inadequate rest after working hours	[28]
Monotony of work	[23]
Poor working environment	[14.23]
Inadequate design knowledge/experience or low technical knowledge by a member of the team	[29]
Unrealistic deadline	[23]
Inadequate staffing	[23]
Sleep deprivation/deficiency	[30]
Poor working relationship among project stakeholders	[23,28]
Poor resource support	[23]
Lack of sense of self-efficacy	[31–33]
Poor leadership	[24]
Limited feedback mechanism	[21,22]
Inadequate concentration during working hours	[23,30]
Less effective collaboration	[34,35]

Source: Authors' compilation.

2.3. Strategies for mitigating fatigue and fatigue-induced human errors in construction projects

Studies on fatigue have been undertaken in a wide range of fields. For instance, Antwi-Afari et al. [36] investigated work-related musculoskeletal problems in construction workers and summarized the risk variables as being associated with repetitive lifting jobs. Fatigue-related risk factors ranked highly among the variables identified. To manage fatigue among workers, and within organizational settings, various studies have identified several strategies and/or countermeasures towards achieving this purpose. To enable proper articulation of the suitability of these strategies for resolving different types of fatigue – physical and/or mental fatigue – scholars have made attempts at delineating these strategies based on various constructs.

Lu et al. [14] categorized strategies for managing physical fatigue into individual-focused, workplace-focused and multiple strategies. Whereas the former which focused on physical fatigue resulting from causative factors relating to the individual, e.g., sleep deprivation, was associated with strategies like assistive device posture variation, exercise and relaxation therapy, the workplace category focused on causes of fatigue emanating from the structure of the workplace and the attendant work practices. Strategies identified for mitigating workplace fatigue included task variation, rest breaks, changes to work pace, etc. [14]. Furthermore, the authors classified strategies such as posture variation and rest break as multiple strategies, indicating a juxtaposition of individual-focused and workplace-focused strategies [14].

Furthermore, Sanquist et al. [15] delineated fatigue mitigation strategies into preventive and operational facets within the context of rapid renewal highway construction projects. To elucidate the degree of efficacy of these strategies, the authors provided three levels of efficacy, i.e., generally effective, less effective or reliable, according to which these identified strategies were classified. In that study, strategies like optimal sleep, napping and improved knowledge about fatigue were classified as generally effective strategies [15]. A summary of fatigue mitigation strategies is presented in Table 2.

Table 2. Fatigue mitigation strategies.

Mitigation strategy	Source
Assistive device posture variation	[14]
Exercise	[14,15]
Relaxation therapy/oral rehydration	[14]
Task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules	[14,19,23]
Provision of rest breaks	[14,30]
Napping during working hours	[15,30]
Worker status monitoring and alerting technologies	[15]
Sleep management education	[23,30]
Fatigue risk management systems	[23]
Multiple ways of providing feedback should be made available for stakeholders	[30]
Heat exposure reduction	[19]
Prevention of work overtime among workers	[30]
Increased degree of teamwork among workers	[19]
Open communication among workers	[15]
Non-isolation of employees from the necessary resources	[19]
Recognition of workers' emotions in terms of strength and weaknesses	[14,15]

Source: Authors' compilation.

Despite the recommendation of 9-min breaks per hour to reduce fatigue among meat-processing workers by Dababneh et al. [37] more than two decades ago, the incidence of fatigue amongst workers persists [14,30,38]. This has led to questions concerning the effectiveness of these strategies across different contexts. Also, the limited nature of studies seeking to evaluate the efficacy or effectiveness of these fatigue mitigation strategies or countermeasures using empirical evidence has been observed [14]. Whereas scholars have made attempts to bridge this gap, their studies have focused on the conventional workplace [14] and rapid renewal highway construction projects [15]. As such, this study is necessitated by such a paucity of studies seeking to evaluate the effectiveness of fatigue mitigation strategies within the mainstream construction industry, with particular emphasis on a developing country context.

Whereas various scholars have indicated the need for the adoption of robust fatigue management systems comprising a juxtaposition of objective and subjective fatigue assessment tools for engendering early detection and management [38,39], an evaluation of these systems is beyond the scope of this study. This study focuses on an evaluation of the perception of construction workers concerning the major causes of fatigue and the degree of efficacy of relevant strategies or countermeasures for fatigue mitigation.

3. Research methodology

3.1. Data collection process

This study investigates the incidence of fatigue and its mitigation as experienced by construction workers in Abuja, Nigeria. Beyond the identification of causal factors, the study establishes the most effective strategies which can be deployed for fatigue mitigation. Adopting a case-study research design, a questionnaire survey was used for eliciting data for the study in a manner depictive of a within-case survey. The questionnaire comprised three sections. The first section contained questions seeking to elicit information concerning the biodata of the respondents. Questions relating to the causes of fatigue among general construction workers were posed in the second section of the questionnaire. In this section, relying on a 5-point Likert scale (see [40–42] for similar scales), respondents were expected to rank the causes of fatigue extracted from the literature according to their degree of significance. In the third section, questions pertaining to the ranking of the fatigue mitigation strategies using a 5-Likert scale were posed. Provisions were made for respondents to identify and rank other causes of fatigue as well as fatigue mitigation strategies. The sample for this study was drawn from an online database of construction companies in Abuja, Nigeria (https://www.finelib.com/cities/abuja/business/construction), using a mix of non-parametric, convenience and snowballing sampling approaches. The list of the various construction companies was searched by the researchers around January 2021.

The choice of Abuja was predicated on the multiplicity of ongoing construction activities prevalent therein [43,44]. As Nigeria's capital city, Abuja is rapidly urbanizing and, as such, is replete with a plethora of construction works to cater to the associated effects of rapid urbanization [45]. At least 61 construction contracting organizations were identified from the database. Subsequently, these construction contracting organizations were formally contacted via email to participate in the study. After a 2-week period and continued prodding by the authors, 35 construction contracting organizations gave consent for their workers to be surveyed. Based on the receipt of this consent, staff working for these organizations were surveyed. Field workers were recruited to carry out the administration of the survey. These field workers visited the various sites and offices of firms over a period of 1 month between February 2021 and March 2021. The field workers self-administered the questionnaires to the study respondents and collected them back from them through the same method. A total of 126 questionnaires were distributed in no particular order and number between the staff of these construction contracting organizations. Whereas 126 responses were obtained, only 111 were deemed useable for this study due to reasons mostly including incomplete questionnaires. This is indicative of a response rate of 88%. The high response rate can be ascribed to the use of a self-administered questionnaire survey. The data from the survey were analysed using inferential statistics. The mean item score (MIS) was used for ranking the causes. Also, Cronbach's α and standard deviation tests were conducted to determine the reliability of the outcome of the 5-point Likert scale adopted. In the tests, variables with a MIS of 3.0 and above were considered very significant [46]. The degree of agreement of all the respondents (of different professions) who participated in the survey was determined through Kendall's correlation coefficient of concordance (W). The literature shows that factor analysis (FA) can be used to reduce a large number of related variables to a more manageable number [47]. It is in view of this that FA was used to reduce the factors responsible for fatigue among construction workers to a significant proportion. This implies that the FA adopted in this study was used to elicit the most significant factors responsible for fatigue among construction workers into categories based on their degree of similarity. Before the use of FA, the suitability of the data for FA was first tested following the three-step test prescribed by the Digital Bridge Institute [47]. These three steps are suitability assessment, factor extraction and factor rotation/interpretation. Hence, in the factor extraction tests, 0.5 and above factor loading with eigenvalues ≥ 1 was accepted while all the variables with factor loading < 0.5

were rejected [47]. IBM SPSS version 23.0 was employed to aid this analysis.

The results obtained from the study are presented and discussed in the following sections.

3.2. Ethics committee approval

This article does not require ethics committee approval because the data collection and analysis processes deployed for the study conformed to known tenets of confidentiality. Accordingly, all information which could culminate in the identification of participants' information was anonymized. Furthermore, questions posed in the data collection instrument did not pose any risk of discomfort, psychological distress or inconvenience to the study's participants. It is imperative to note that the participants of the study consented to participate in the study before participating. They were also made aware of their inalienable rights to withdraw from the study at any point without any penalty. We hereby declare that the study conducted was not invasive and ethic committee approval was not necessary because the Federal University of Technology Minna, Nigeria (the lead author institution) status currently does not mandate the application and granting of ethical clearance for studies being led by academic staff at the institution. Consequently, the consent of the study participants will not be challenged now or later for any reason by any individual, body or organization. The global trends towards an increasing need to ensure ethical conduct among researchers is highly appreciated. We hereby reiterate that the inability of Federal University of Technology Minna, Nigeria to align with this trend does not disprove or invalidate the quality of data utilized for studies carried out by the institution academic staff, as every member of staff in the institution has sworn to uphold academic standard and research integrity.

4. Results

4.1. Causes of fatigue among Nigerian construction workers

Based on the opinions of the respondents on the valid 111 questionnaires that were returned (88% response rate of the total distributed), the underlying factors responsible for fatigue among workers on Nigerian construction projects are presented in Table 3. The high α value of 0.931 (excellent) obtained from the respondents indicates the reliability and acceptability of the 5-point Likert-scale data [48,49]. The standard deviations obtained in the analysis are also within the acceptable range, as they indicate that there were low variations in the responses among the respondents [50]. Further, the W values obtained range from 0.719 to 0.972 at the two-tailed significant level of 0.000 ($p < 0.05$). This infers a general agreement on the ranking of the respondents irrespective of their discipline and experience and the nature of projects handled over the years [51].

According to Table 3 it is clear that, except for unexpected changes or situations, all of the variables identified in the literature phase of the study were rated high by the respondents and can be emphasized as the causes of fatigue among construction workers within the study context. In other words, the mean score rating above 3.00 which was accepted implies that 19 variables are the key causes of fatigue. However, a variable with a mean score rating below 3.00 was rejected. Unexpected challenges or unforeseen situations in the construction process are not considered a cause of fatigue. Premised on the outcomes of the study conducted, it can be contended that the causes of fatigue such as excessive workloads that individuals cannot cope with, inadequate rest during/after working hours and depression/frustration by construction workers are also the causes of error among employees in the construction process. It can also be observed that some of the variables in the table, e.g., inadequate rest during and after working hours, work pressure and excessive workloads that individuals cannot cope with, are very close in terms of their MIS. This infers that such variables are similar or related and may be reduced or overcome with a single concept or method in projects [51]. Therefore, an analysis that can be used to group the variables together is essential [51].

4.2. Factor analysis of underlying causes of fatigue among construction workers in Nigeria

FA was used to analyse and group the 19 significant causes of fatigue into more significant, related and manageable categories. According to Curran [52], FA is a general term used for a family of techniques in which principal component analysis (PCA) is a main member. PCA was used to determine the existence of any relationships amongst the 19 variables and factor extraction for effective conclusion on the underlying causes. The first step in the analysis was to determine the factorability and suitability of the variables concerned. The sample size of 111 and the number of variables ($n = 19$) were adequate and subsequently considered satisfactory for the FA test. Inspection of the correlation matrix revealed the presence of coefficients ranging from 0.06 to 0.360, which is satisfactory [53]. In addition, the values of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity in IBM SPSS version 23.0 used were between 0.5 and 0.7, with $p < 0.05$ (adequate) supporting the factorability of the correlation matrix [52] (see Table 4).

Following the determination of the suitability of the data for FA, FA was thus conducted (see 5). The FA test revealed six underlying factors responsible for fatigue among Nigerian construction workers. The results presented in Table 5 summarize the factor loading on each of the six extracted factors and their variables.

The FA test revealed the presence of six components with eigenvalues exceeding 1, explaining 28.084, 26.147, 18.131, 9.464, 3.981 and 2.962% of the variance, respectively [52], as presented in Table 5. The six components explain a total of 88.769% of the variance, which is satisfactory [53].

According to Spector [54], a clear component structure is present when a variable has a significant factor loading (> 0.50) on one component only. Hence, only elements (variables) ≥ 0.5 were considered under each component. Further, varimax rotation with Kaiser normalization was performed to confirm the adoption of the grouping of the six-component solutions. These results are presented in Table 6. The rotated solution in the varimax rotation further revealed the presence of a simple structure with the six components showing a number of strong loadings, indicating that the six components are good for adoption in this study [53].

Hence, the FA conducted reduced the 19 underlying cases of fatigue into six major components (ECA1–ECA6). Table 7 presents a summary of the re-grouped underlying causes of fatigue among construction workers in Nigeria.

Table 3. Causes of fatigue among construction workers in Nigeria.

Cause of fatigue in projects	MIS	*SD*	α	*W*	Ranking	Remark
Inadequate rest during and after working hours (CA1)	4.37	0.718	0.931	0.873	1st	Accepted
Frustration/depression or work pressure (CA2)	4.33	0.913		0.871	2nd	Accepted
Excessive workloads that employees cannot cope with (CA3)	4.31	0.816		0.911	3rd	Accepted
Poor communication among workers (CA4)	4.27	0.821		0.749	4th	Accepted
Unrealistic deadline (CA5)	4.23	0.921		0.876	5th	Accepted
Poor working relationship among project stakeholders (CA6)	4.21	0.769		0.721	6th	Accepted
Lack of orderliness among workers (CA7)	4.17	0.873		0.812	7th	Accepted
Poor resource support (CA8)	3.58	1.121		0.891	8th	Accepted
Lack of sense of self-efficacy (CA9)	3.39	0.988		0.874	9th	Accepted
Sleep deprivation/deficiency (CA10)	3.35	1.156		0.924	10th	Accepted
Awkward working postures (CA11)	3.32	0.161		0.972	11th	Accepted
Poor working environment (CA12)	3.31	0.929		0.819	12th	Accepted
Poor safety leadership (CA13)	3.27	1.171		0.761	13th	Accepted
Less effective collaboration (CA14)	3.25	0.871		0.914	14th	Accepted
Inadequate design knowledge/experience or low technical knowledge by a member of the team (CA15)	3.22	1.307		0.792	15th	Accepted
Limited feedback mechanism (CA16)	3.17	0.171	–	0.931	16th	Accepted
Inadequate concentration during working hours (CA17)	3.11	1.293	–	0.767	17th	Accepted
Inadequate staffing (CA18)	3.07	1.219	–	0.781	18th	Accepted
Monotony of work (CA19)	3.02	0.834	–	0.719	19th	Accepted
Unexpected challenges or unforeseen situation in construction process (CA20)	2.51	1.267	–	0.819	20th	Rejected

Notes: CA1–CA20 = causes of fatigue in construction projects; MIS = mean item score; *W* = Kendall's correlation coefficient of concordance.

Table 4. Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test (underlying causes of fatigue among construction workers in projects).

Parameter		*Value*
KMO measure of sampling adequacy		0.618
Bartlett's test of sphericity	Approximate χ^2	498.379
	df	19.00
	p	0.0000

Extracted components ECA1–ECA6 were used to obtain the opinions of the respondents on the strategies that can be adopted to reduce the causes of fatigue-induced error among construction workers in the second round of the survey exercise (see the next section). In each of the extracted causes of fatigue, several strategies were rated high by the respondents of the survey study. Table 8 presents the most appropriate strategies for mitigating fatigue caused by each of the groups of causative factors.

5. Discussion of results

Various modes for categorizing fatigue mitigation strategies have been articulated in previous studies. In their study which sought to assess the effectiveness of various fatigue mitigation strategies, Lu et al. [14] presented strategies which were most effective for managing individual-focused and workplace-focused fatigue causative factors as well as the strategies which can be used in the case of causative factors which belong to both categories. Similarly, Sanquist et al. [15] classified these strategies into preventative and operational categories, respectively, and outlined their degree of effectiveness in tackling various fatigue causative factors.

In this study, these strategies were grouped according to their utility in mitigating fatigue causative factors belonging to a particular grouping as established from the FA. Such categorization enables an easy determination of the appropriate mitigation strategy/strategies to deploy to mitigate the incidence of certain causes of fatigue among construction workers. This much was acknowledged by Sanquist et al. [15] and Lu et al. [14] in their studies which assessed the efficacy of different fatigue mitigation strategies. Although these scholars sought to fill this gap through their studies, certain gaps persist. Firstly, the assessment carried out by Lu et al. [14] focused on a generic contextual plane without particular emphasis on the construction industry or project environment. Although Sanquist et al. [15] carried out their assessment of the efficacy of the fatigue mitigation strategies within the construction industry context, the scope of their study was delimited to rapid renewal highway construction projects. Obviously, this project typology is associated with various attributes which distinguish it from other kinds of construction projects. Accordingly, results from both studies as they relate to the subject matter can be deemed to be either generic or narrow as they do not cater to the experiences of construction workers or construction projects in a comprehensive way. This is a gap which the current study contributed towards bridging as it explores the perspectives of construction workers working across a wider spectrum of construction projects, albeit within a particular geographic context.

Efforts were made to decipher the degree of effectiveness of different strategies for mitigating the incidence of fatigue among construction workers relying on the perspectives of the respondents. Results indicate that the factor category comprising fatigue variants resulting from excessive workloads that employees cannot cope with (ECA1) can best be mitigated by educating workers on the core tenets of sleep and fatigue management. The criticality of deploying education or training of construction workers on sleep and fatigue management towards ensuring effective mitigation of fatigue among construction workers has been highlighted previously [30]. The modification of company or project policies and guidelines towards boundary setting to prevent overworking (overtime) among workers as well as establishment of nap regimes during work hours were ranked second and third, respectively, for mitigating fatigue resulting from the causative factors associated

Table 5. Varimax rotation for FA.

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.223	28.084	28.084	3.223	28.084	28.084
2	2.407	26.147	54.231	2.407	26.147	54.231
3	1.511	18.131	72.362	1.511	18.131	72.362
4	1.907	9.464	81.826	1.907	9.464	81.826
5	1.855	3.981	85.807	1.855	3.981	85.807
6	1.602	2.962	88.769	1.602	2.962	88.769
7	0.993	2.475	91.244	–	–	–
8	0.851	2.065	93.309	–	–	–
9	0.765	1.044	94.353	–	–	–
10	0.711	1.022	95.375	–	–	–
11	0.672	1.001	96.376	–	–	–
12	0.512	0.931	97.307	–	–	–
13	0.478	0.801	98.108	–	–	–
14	0.347	0.691	98.799	–	–	–
15	0.267	0.389	99.188	–	–	–
16	0.211	0.217	99.405	–	–	–
17	0.190	0.206	99.611	–	–	–
18	0.121	0.198	99.809	–	–	–
19	0.095	0.191	100.00	–	–	–

Note: FA = factor analysis

Table 6. Pattern matrix for FA.

Underlying cause of fatigue in construction projects	Rotated component matrix					
	1	2	3	4	5	6
Frustration/depression or work pressure	0.918	–	–	–	–	–
Inadequate staffing	0.816	–	–	–	–	–
Poor resource support	0.731	–	–	–	–	–
Unrealistic deadline	0.674	–	–	–	–	–
Poor leadership	0.611	–	–	–	–	–
Lack of orderliness among workers	–	0.893	–	–	–	–
Poor working relationship among project stakeholders	–	0.791	–	–	–	–
Monotony of work	–	0611	–	–	–	–
Less effective collaboration	–	0.533	–	–	–	–
Limited feedback mechanism	–	0.591	–	–	–	–
Lack of sense of self-efficacy	–	–	0.771	–	–	–
Unexpected challenges or unforeseen situation in construction process	–	–	0.653	–	–	–
Inadequate design knowledge/experience or low technical knowledge by a member of the team	–	–	0.631	–	–	–
Awkward working postures	–	–	–	0.741	–	–
Unrealistic deadline	–	–	–	0.673	–	–
Poor working environment	–	–	–	0.581	–	–
Sleep deprivation/deficiency	–	–	–	–	0.621	–
Poor communication among workers	–	–	–	–	0.598	–
Inadequate rest after working hours	–	–	–	–	–	0.591

Note: FA = factor analysis.

with ECA1. These results bear a resemblance to the results from Pencaval. [55], wherein the authors identified modification of the work schedule and a conducive sleep environment and napping as generally effective strategies for mitigating fatigue among construction workers. Similarly, Phegley [23] and Caldwell et al. [30] elucidated the effectiveness of naps and work schedules for mitigating the incidence of worker fatigue. However, these authors did not elicit the degree of effectiveness of these strategies when compared to alternatives.

Concerning fatigue causative factors relating to poor communication among workers (ECA2), the respondents identified strategies ranging from team building and bonding among workers to the institution of open communication protocols among workers as well as non-isolation of necessary resources from workers as ranking from first to third place in their assessment. This result corroborates the assertion made by scholars like Hallowell [19] that indicated the significance of an increased degree of teamwork in mitigating fatigue among construction workers.

Working relationship problems among project stakeholders (ECA3) was identified as another factor category of fatigue causative factors ranging from the lack of sense of self-efficacy

Table 7. Re-grouping of the underlying causes of fatigue in construction projects.

Cause	Initial	Loading weight
Component 1: excessive workloads that employees cannot cope with (ECA1)	1	–
A. Frustration/depression or work pressure	–	0.918
B. Inadequate staffing	–	0.816
C. Poor resource support	–	0.731
D. Unrealistic deadline	–	0.674
E. Poor leadership	–	0.611
Component 2: poor communication among workers (ECA2)	1	–
A. Lack of orderliness among workers	–	0.893
B. Poor working relationship among project stakeholders	–	0.791
C. Monotony of work	–	0611
D. Less effective collaboration	–	0.533
E. Limited feedback mechanism	–	0.591
Component 3: working relationship problem among projects stakeholders (ECA3)	1	–
A. Lack of sense of self-efficacy	–	0.771
B. Unexpected challenges or unforeseen situation in construction process	–	0.653
C. Inadequate design knowledge/experience or low technical knowledge by a member of the teams	–	0.631
Component 4: poor management support (ECA4)	1	–
A. Awkward working postures	–	0.741
B. Unrealistic deadline	–	0.673
C. Poor working environment	–	0.581
Component 5: inadequate concentration during working hours (ECA5)	1	–
A. Sleep deprivation/deficiency	–	0.621
B. Poor communication among workers	–	0.598
Component 6: employees resting challenge (ECA6)	1	–
A. Inadequate rest after working hours	–	0.591

Note: ECA1–ECA6 = re-grouped causes of fatigue in construction projects

Table 8. Prioritization of mitigation strategies.

Cause of fatigue	Mitigation strategy	MIS	*SD*	α	*W*	Rank
ECA1	Sleep and fatigue risk management education	4.81	0.911	0.97	0.811	1st
	Boundary setting to prevent overworking (overtime) among workers	4.76	0.712		0.913	2nd
	Establishment of nap regimes during work hours	4.73	0.971		0.822	3rd
ECA2	Team building and bonding among workers	4.67	0.925	–	0.920	1st
	Encourage open communication among workers	4.61	0.914	–	0.974	2nd
	Non-isolation of employees from the necessary resources	4.53	0.961	–	0.947	3rd
ECA3	Recognition of workers emotion in terms of strength and weaknesses	4.67	0.743	–	0.919	1st
	Increase the degree of teamwork	4.43	0.913	–	0.877	2nd
	Multiple ways of providing feedback should be made available for stakeholders	4.32	0.813	–	0.719	3rd
ECA4	Worker status monitoring and alerting technologies	4.32	0.930	–	0.974	1st
	Increase the degree of teamwork	4.17	0.982	–	0.991	2nd
	Assistive device posture variation	3.87	0.821	–	0.727	3rd
ECA5	Provision of rest break	4.71	0.823	–	0.911	1st
	Heat exposure reduction	4.62	0.990	–	0.912	2nd
	Task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules	4.45	0.872	–	0.772	3rd
ECA6	Task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules	4.78	0.891	–	0.719	1st
	Relaxation therapy	4.65	0.829	–	0.721	2nd
	Exercise	4.55	0.911	–	0.877	3rd

Note: ECA1–ECA6 = mitigation strategies for causes of fatigue in construction projects; MIS = mean item score; *W* = Kendall's correlation coefficient of concordance.

among construction workers to low technical knowledge by a member of the team. Scholars have identified the role of self-efficacy in predicting the incidence of burnout and engagement with tasks among workers [33,56–58]. However, these studies do not focus on the impact of this causative factor within the construction industry context. In addition to establishing this factor category (ECA3), mitigation strategies such as recognition of the workers' emotional needs and areas of strength and weakness, encouragement of improved levels of collaboration (teamwork) as well as the provision of feedback to workers were ranked in this order as the most suitable strategies for tackling the incidence of fatigue emanating from causative factors associated with ECA3. Mitropoulos and Memarian [35] elucidate the need for improved levels of teamwork (collaboration) as a panacea for mitigating the incidence of overwork and attendant fatigue among construction workers. For such levels of collaboration to be achieved, the need for the enactment of relevant guidelines on construction sites as well as proper delineation of tasks among construction workers based on their areas of strength and weakness cannot be overemphasized [14].

According to the respondents, a common thread relating to poor management support (ECA4) on construction projects was observed among some of the fatigue causative factors identified. Factors listed under the ECA4 category include poor working environment and awkward postures among workers. Nahrgang et al. [59] interrogated the extant interrelationship between job demands, level of available resources, burnout, degree of worker engagement with assigned activities and safety performance on construction projects. In their study, they observed that increasing job demands in the face of limited job resources was a significant determinant of high levels of burnout among workers resulting in underwhelming safety outcomes. Furthermore, awkward posture remains a major cause of fatigue among construction workers [60–63]. Akanmu et al. [64] describe awkward posture as positions adopted by workers which are considered a deviation from the neutral body-segment position during the execution of tasks such as repetitive lifting jobs. Besides contributing to fatigue among construction workers, Palikhe et al. [65] in a recent study traced the incidence of musculoskeletal disorders (MSDs) to awkward postures adopted by construction workers when performing tasks.

Respondents ranked the use of appropriate monitoring and alerting technologies as the most effective strategy for mitigating fatigue resulting from causative factors belonging to ECA4. Additionally, an increased degree of teamwork and the use of assistive device posture variation ranked second and third, respectively. Lu et al. [14] concur on the utility of posture variation in managing individual-based and workplace categories of fatigue causative factors. Similarly, Sanquist et al. [15] admitted the potential usefulness of monitoring and alerting technologies. However, they remained sceptical of its potency in the rapid renewal construction project environment. Based on the plethora of projects in which this study's respondents were involved, it can be inferred that the use of such technologies remained critical to the mitigation of fatigue associated with ECA4 across different project typologies.

Based on the results from the FA, it was observed that fatigue causative factors like sleep deprivation and/or deficiency and poor communication were categorized as ECA5. ECA5 was classified as comprising causative factors which facilitate inadequate concentration during working hours among construction workers. To mitigate the incidence of fatigue emanating from the so-grouped causative factors, the respondents in the study identified the provision of rest breaks as the most potent mitigation strategy. This strategy was followed by the reduction of heat exposure reduction and task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules in second and third place, respectively.

Lastly, a causative factor of inadequate rest after working hours was categorized under the employees' resting challenge (ECA6). To curb this category of a factor, results indicate that the deployment of task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules ranked as the most suitable mitigation strategy whilst relaxation therapy and exercises ranked second and third, respectively.

Based on the foregoing, it can be discerned that there is no 'one-size fits all' strategy for mitigating the incidence of various fatigue causative factors among construction workers. According to the responses elicited from the construction workers who participated in this study, different mitigation strategies are better placed to curb the incidence of these causative factors, hence culminating in a reduction of the levels of fatigue experienced by construction workers. However, judging from the rankings provided, it is obvious that mitigation strategies like task variation/changes to work pace/strategic work rotation/reduced pace of work/work schedules and improved levels of teamwork remain predominant for tackling fatigue among construction workers.

6. Conclusion

Fatigue remains a significant contributor to the increasing number of accidents and fatalities on construction sites globally. This observation has seen an overt concentration of efforts by various stakeholders within academia and industry to tackle the phenomenon. These efforts have led to the establishment of various strategies for mitigating fatigue among construction workers. Whereas a plethora of mitigation strategies have evolved because of these concerted efforts, a paucity of studies seeking to assess their effectiveness has been observed. Without such information, it may be difficult for relevant actors to properly tackle the incidence of fatigue. This knowledge gap has led to the present study.

Using the responses elicited from workers ($n = 111$) operating under the auspices of construction companies carrying out projects in Abuja, Nigeria's Federal Capital City, using survey questionnaires, the study identified the causative factors leading to fatigue among construction workers, various mitigation strategies, performed a categorization of these causative factors using FA and, subsequently, ranked each of the 19 fatigue mitigation strategies identified from the literature according to their perceived potency in tackling these established causative factor categories. The results from the study elucidate the absence of an overall strategy for mitigating fatigue among construction workers. In addition, the study concludes that some mitigation strategies are most effective compared to others based on the nature of the fatigue causative factors. Although limited to the responses from a population of construction workers ($n = 111$) operating within a particular geographical context (Abuja, Nigeria) and without taking cognizance of the nature of the construction projects with which they were mainly involved, the results of the survey bear considerable implications for relevant stakeholders. These are highlighted as follows:

- the study provides insight into the perceptions of construction workers regarding the effectiveness of different fatigue mitigation strategies;
- such insight provides a platform for the articulation of a framework for administering effective fatigue management among construction workers;
- the study allows for an appreciation of the nexus between different fatigue and causative factors;
- the study provides a platform for engendering further studies.

The use of the survey research design lends the study to certain limitations. For example, the list of fatigue causative factors and fatigue mitigation strategies evaluated were deduced from the extant literature. As such, there was no opportunity for new factors or mitigation strategies to be elicited from the respondents. This may have been a missed opportunity to identify context-dependent factors or strategies. To cater to this limitation, it is expected that future studies may adopt a mixed-method research design when conducting similar evaluations. Furthermore, no attempt was made at comparing the levels of effectiveness of these mitigation strategies in combating fatigue across a range of construction project typologies. The uniqueness of different construction projects is evident. Therefore, different projects will come with a distinct range of attributes which may impact on the effectiveness of fatigue mitigation strategies. Scholars can investigate this possibility through further studies. Lastly, the sample size is not considered representative of the entirety of the construction industry workforce in Abuja or Nigeria because of the lack of a credible database. Whilst this does not negate the contribution of the study to the relevant knowledge domain or its implications thereof, there is a need for future studies to utilize a wider sample of the population for data elicitation, thereby facilitating statistical generalizability of the results.

Disclosure statement

No potential conflict of interest was reported by the authors.

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