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Technological and Engineering Solutions to Prevention and Reduction of Hand Arm Vibration Syndrome in the Construction Industry

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ABSTRACT

Prolonged exposure to hand arm vibration (HAV) can lead to hand arm vibration syndrome (HAVS), which poses serious health risks for workers (Lache & Luculescu, 2008). This paper employs a five-stage scoping review to explore technological and engineering solutions to mitigate HAV exposure in the construction sector. Key strategies identified include process modifications, reducing continuous vibration exposure, training programs to promote best practices, and using personal protective equipment such as anti-vibration gloves. Additionally, substituting low-vibration tools is recommended as an effective measure to decrease HAV exposure. The findings indicate that engineering solutions can significantly reduce the health impacts of HAV. The paper calls for further research, especially in developing regions like Africa, to evaluate HAVS prevalence in construction and to adapt control measures to local conditions. Overall, this study provides essential insights into preventing HAV, highlighting the need for global attention to this occupational health issue in the construction industry.

Keywords: Hand ARM vibration syndrome, Construction industry, Construction workers, Technological and engineering solution, Mitigating and reduction of HAVS

INTRODUCTION

Hand Arm Vibration (HAV) is a significant health risk in industries such as construction and mining, leading to Hand-arm vibration syndrome (HAVS), which encompasses vascular and neurological disorders (Lewkowski et al., 2021; Lache & Luculescu, 2008). Factors influencing severity include vibration frequency, magnitude, and exposure duration (Coggins et al., 2010). Symptoms range from numbness to reduced grip strength (Edwards et al., 2020). Despite awareness, prevention is often obstructed by worker behavior (Leduc et al.).

LITERATURE REVIEW

Hand Arm Vibration Syndrome (HAVS) is an occupational disorder resulting from prolonged exposure to hand-arm vibrations, leading to symptoms like pain and reduced grip strength (Lai et al., 2019). Despite its impact, HAVS is often undervalued in construction due to compliance challenges and individual health factors (Edwards and Holt, 2005; Weir and Lander, 2005). The industry faces significant risks from tools such as power planners and pneumatic breakers, with up to 50% of U.S. workers potentially affected (Edwards et al., 2020). Effective prevention strategies include using low-vibration tools, planning, education, and strong regulations (Nachmias and Nachmias, 1996).

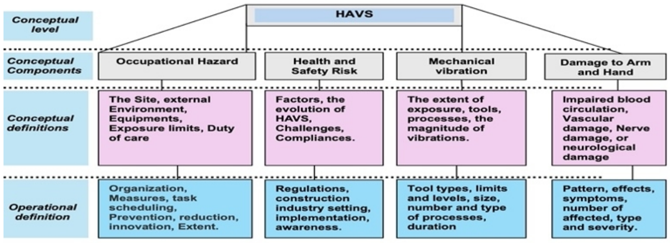

Figure 1: Hand arm vibration syndrome (HAVS) as a concept outlines HAVS through conceptual definitions and operational definitions (Nachmias & Nachmias, 1996).

METHODS

A scoping review analysed the literature on technological and engineering solutions for preventing HAVS from 1990 to 2023, focusing on the under researched construction sector in developing nations (Botti et al., 2020). The review methodology, effective in identifying existing studies and trends (Thorley et al., 2019; Osobajo et al., 2020), involved five stages: formulating questions, locating studies, selecting and evaluating them, and reporting results. This approach benefits construction engineering and management (CEM) research, aiding data synthesis and future direction suggestions (Aarseth et al., 2017; Badi and Murtagh, 2019; Dixit et al., 2019).

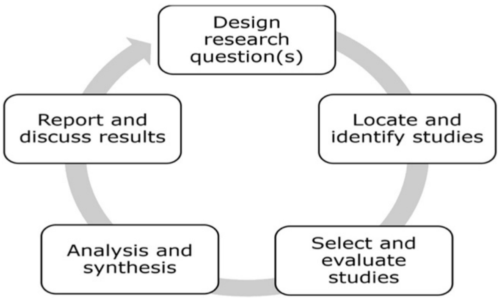

Figure 2: Scoping review process (Denyer and Tranfield, 2009) as quoted (Osobajo et al., 2020).

The Five Stages of a Scoping Review

Stage 1: Formulation of Research Questions

What trends and research focus areas exist regarding HAVS in the construction industry, what is the current understanding of technological solutions for prevention and reduction, and what potential future directions can be anticipated in this field?

Stage 2: Locate and Identify Relevant Studies

A literature search using Scopus and Web of Science was conducted for construction and engineering domains, ensuring efficient article selection (Akomea Frimpong et al., 2022; Zhang et al., 2016).

Consistent HAVS-related keywords were applied across both databases. In the Scopus, it read: 'TITLE-ABS-KEY (hand AND arm AND vibration AND vibration AND syndrome OR vibration OR syndrome AND construction AND industry OR construction AND workers)'. On the Web of Science, the keywords included: 'Hand AND arm AND vibration AND vibration AND (syndrome OR vibration) AND (construction OR "construction industry") AND workers.

The initial, unfiltered outcome of the search revealed 159 documents (90 in Scopus and 79 in the Web of Science). The search period was unrestricted until 2023. The final outcome was subjected to several inclusions and exclusion criteria, as discussed in stage 3.

Stage 3: Selecting and Evaluating Studies

The selection process involved scanning 159 retrieved articles based on titles, abstracts, and methodologies and applying specific inclusion and exclusion criteria (Figure 3). Criteria included language, source type, and document type, leading to removing duplicates and filtering down to 72 relevant documents (55 from Scopus and 11 from Web of Science). Articles must be published in recognized journals and adequately cover Hand-Arm Vibration Syndrome (HAVS). Ultimately, 66 articles met the criteria for inclusion in this systematic literature review.

Table 1. Inclusion and exclusion criteria for Stage 2 of study identification (Author).

Criteria	Inclusion	Exclusion	Rationale
Academic database	Scopus & Web of Science	Other than Scopus & Web of Science	To authenticates the findings.
Type of research	Published journal articles, book chapters, conference papers, postgraduate research and grey areas.	Review articles, reviews, conference,unpublished correspondences.	N/A
Publication status	Published articles in official sources.	Unpublished articles	N/A

(Continued)

Table 1. Continued

Criteria	Inclusion	Exclusion	Rationale
Year of publication	Articles published from 1990 to 2023.	Articles published before 1990.	30 years gap in old & latest.
Access type	Access to full text, abstract & articles shared by authors.	Those denied by authors.	To widen the scope.
Language	Articles published in English language.	Articles in Language other	N/A
Research area	Research from exposure to vibration.	Research not on vibrating tools	To exclude other vibration types.
Country of origin	Global/ Africa	N/A	There is not much research on HAVS in Africa.
Country of use.	Africa	N/A	To inspire local context

Stage 4: Analysis and Synthesis

Figures 2 and 3 show that only 66 studies were worthy of analysis. Beyond quality, the reviewed articles were evaluated for reliability (Denyer and Tranfield, 2009) and relevance to this study.

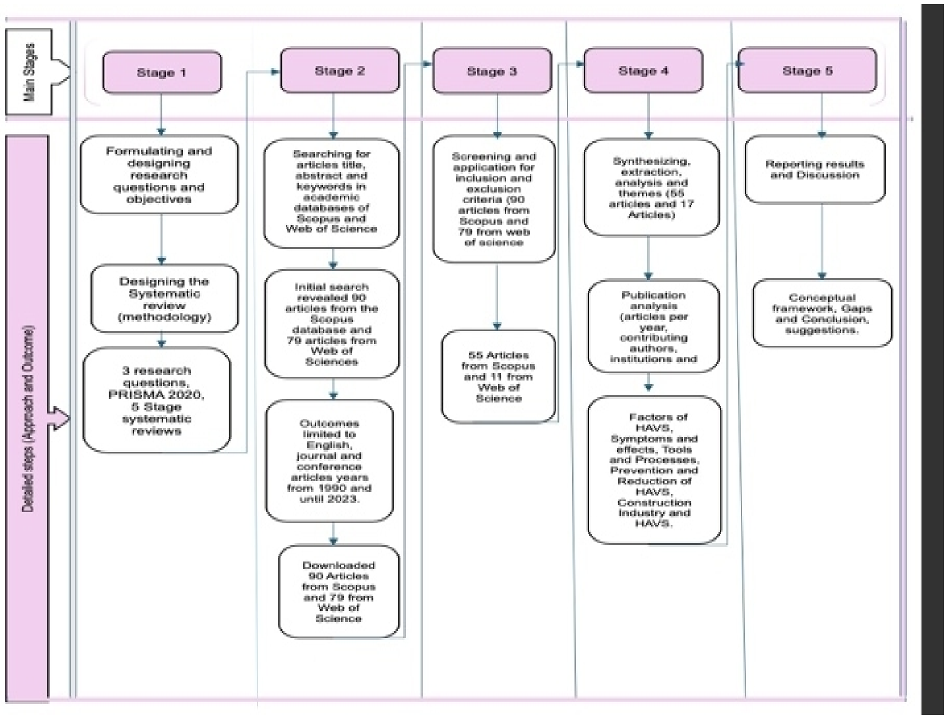

Figure 3: Flowchart presentation of the methodological approach used.

Stage 5: Reporting and Discussion of Results

Reporting findings on this scoping review on HAVS focuses on revealing what the scoping review research on HAVS has shown in what has been researched, furthering the landscape, global trend, and direction of research, and discussing its implications.

RESULTS AND DISCUSSION

Type of Material and Source

Figure 4 demonstrates that 69.4% of HAVS searches came from SCOPUS and 30.6% from Web of Science. Articles and journal articles from Scopus or Web of Science dominated, followed by conference papers. The percentage of dissertation/thesis notes was insignificant. This suggests that the construction sector lacks HAVS-related journal articles, conference papers, dissertations, and theses. Two important research databases have few construction industry HAVS papers. Article and journal articles are synonymous.

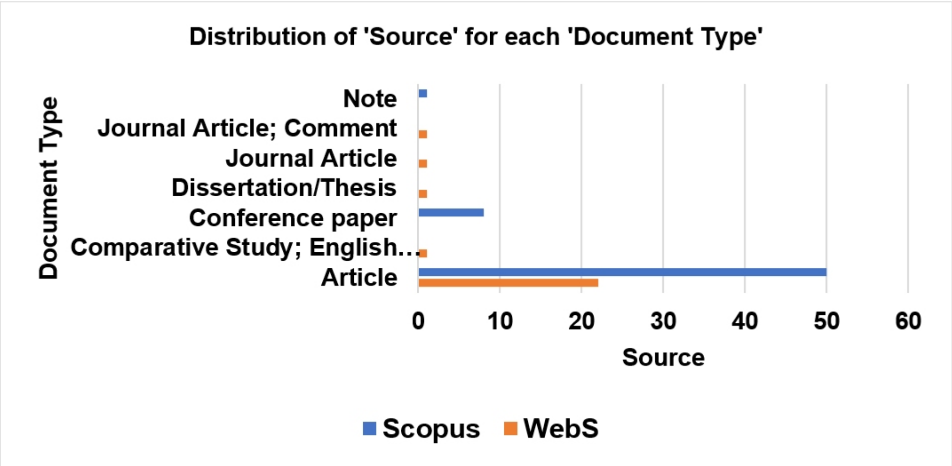

Figure 4: Source and type of materials on HAVS identified in the searches.

Range of Years of Publication

From 1990 to the present, Figure 5 shows that HAVS publications in the construction industry were inconsistent, with some years between 1992 and 2010 lacking publications. From 2010 to 2023, publications occurred every other year, an improvement over the previous ten years. This shows a shift in HAVS research in the construction industry, a notable trend.

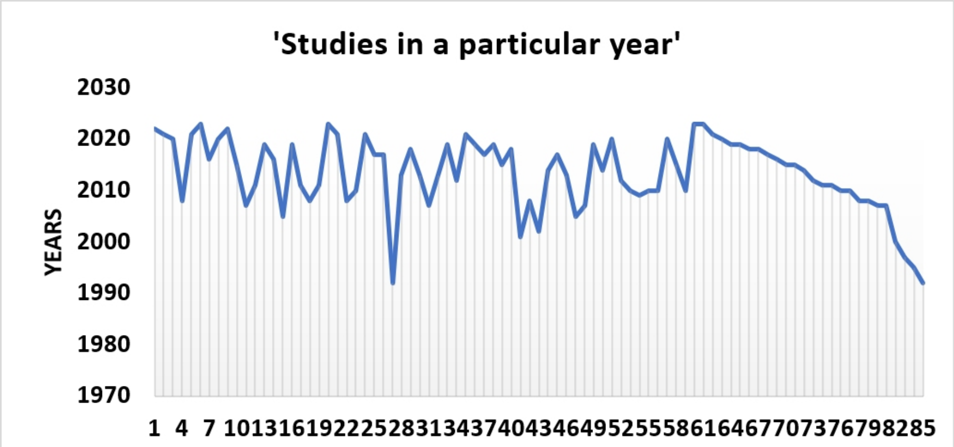

Figure 5: Year range of studies searched and reviewed.

The analysis reveals that most articles are published in Environmental Health, Medicine, and Ergonomics, lacking representation from construction and engineering disciplines. Notably, no African journals are included, raising questions about the significance of citations and authorship (Figure 5; Table 2).

Construction Industry HAVS Research Trends

HAVS Terminologies

Hand-Arm Vibration: Hand-arm vibration affects workers using vibrating tools, necessitating understanding its impact on construction (Edwards et al., 2020).

Hand-Arm Vibration: Syndrome Prolonged hand vibration from tools causes hand-arm vibration syndrome (HAVS), leading to neurological issues, vascular disorders, and pain (Clemm et al., 2022; Lai et al., 2019).

Factors of HAVS

Extended exposure to hand-arm vibrations (HAV) can lead to health issues, but not all exposures result in adverse effects. Key factors influencing symptoms include vibration magnitude, duration, frequency, grip strength, and specific hand areas exposed (Leduc et al., 2016; Bodley et al., 2015). Effective occupational health programs face challenges like scheduling conflicts and multiple contractors, complicating safety messaging (Leduc et al., 2016; Bodley et al., 2015). HAVS symptoms develop gradually, often delaying medical help due to provider unawareness (Leduc et al., 2016; Edwards and Holt, 2007). External factors like posture and individual susceptibility also impact HAVS risk (Nawayseh & AlBaiti, 2023).

Construction Tools Causing HAVS

Handheld vibrating tools are common in construction, with variations in size, weight, and frequency affecting their use. Key factors include vibration impulsiveness, direction, exposure intermittence, work methods, contact force, and operator posture (Park et al., 2018). Most studies identified specific hand-held tools as significant vibration sources.

Table 2. Construction tools causing HAV.

Tool Type	Studies	Machines	Studies
Power tool, Concrete breakers, Grinders, Impact drills, Powered cutters, Chain saws, Jackhammer, Electric Hammer Drill, Impact wrenches, Plate vibrator, Compactor, Power trowel, Power trowel propeller, Pneumatic Hammer, Demolition Hammer, cutting table, Ram, Circular Saw, Drill, Vibrator.	15, 40,16, 23 & 24, 25, 26, 32,	Forklift, Mini Dagger, Damper, Dumper Ride on Lawnmower Single & Double cab pick-up, Tractor, Excavator driving), Excavator (tracking), Chipping machine, Excavator (breaking).	32

Source: Author compilation

(Tan et al., 2019)[15], (Su et al., 2016) [16], (Jain A. R. Tony et al., 2021) [23], (Johnson, B., et al., 2017) [24], (Antonucci et al., 2017) [25], (Brismar Ekenvall, 1992) [26], (Clemm et al., 2020) [32], (Palmer, et al., 2001).

Manufacturers provide vibration data indicating levels and exposure limits influenced by national regulations. While tool design should prioritize vibration reduction, studies highlight the necessity of enhancing workplace conditions to further minimize exposure levels.

Construction Trades and Processes

The construction industry poses significant HAV exposure risks, particularly from activities like demolition and carpentry (Edwards and Holt, 2007). However, there is a lack of categorization among trades and construction phases regarding exposure levels, which is crucial for effective prevention and control.

Symptoms and Effects of Exposure to Vibration

Table 3. Summary of symptoms and effects of HAVS.

	Symptoms	Effects	Body Experience	Studies
HAVS	Vascular	Vasospasm (Vibration White Finger -VWH)	Tingling, numbness and dullness of the fingers in cold.	02, 12, 05, 13
	Neural	Sensorineural disturbances', Peripheral Neuropathy	Tingling, reduced sense of touch, sensitivity to temperature	05, 02
	Muscular	Muscular weakness, Fatigue,	Pain in the upper extremities, impaired grip strength, osteoarthritis.	28, 36

Source: Author

(Leduc et al., 2016) [02], (Edwards et al., 2020)[05], (Bodley et al., 2015) [12], (Edwards and Holt, 2007) [13], (Park et al., 2018) [28], (Rempel et al., 2017a) [36].

Common HAVS symptoms include loss of sensation, tingling, and numbness in hands (Park et al., 2018), as shown in Table 5. Long-term exposure leads to reduced grip strength and task difficulties.

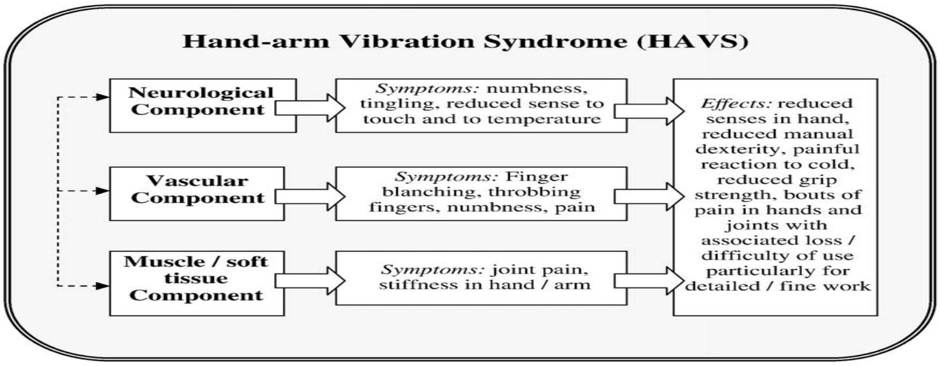

Figure 6: Principal features of HAVS medical groupings. Adopted from (Edwards and Holt, 2010a).

Diagnosing HAVS is challenging and costly, leading to limited research interest. Symptoms manifest slowly, complicating prevention and treatment, often resulting in irreversible conditions (Table 5; Figure 6).

How Has the Research on HAVS Been Done, and the Main Areas

Research on Hand Arm Vibration Syndrome in the construction industry emphasizes exposure assessment, particularly with tools like hammer drills, but lacks effective prevention strategies. Methodologically, studies have relied on estimation and experimental approaches, yet challenges in quantifying vibrations persist. Medical examinations are infrequent due to constraints, with surveys often guiding experiments. The literature reveals limitations in data collection methods and sample sizes, particularly concerning equipment and climatic conditions, which affect generalizability. Furthermore, there is limited research on the impact of smoking, with a predominant focus on Europe and North America, while studies from Asian and African countries are scarce. This raises concerns about HAVS awareness among African construction workers and emerging markets. While safety is prioritized, the insufficient focus on employee wellness regarding HAVS highlights the need for comprehensive research and awareness initiatives to protect worker health in the construction sector.

Table 4. Proposed engineering and technological solution from studies.

Study Focus	Engineering and Technological Solution
Prevalence of HAVS. (Lewkowski et al., 2021)	Estimation, Concludes on Proposing engineering controls as the starting point for exposure reduction strategies.
HAV exposures (De Silva and Wijewardana, 2021)	Exposure measurement, vibration tool specific and task specific in reducing HAV transmitted while enhancing manual dexterity and grip strength.
HAV workers exposure level. (Edwards et al., 2020)	Probability, Proposition of innovation to reduce vibration
Evaluation of Hand Arm Vibration levels. (Forouharmajd et al., 2011)	Measurement and prediction of Vibration "Pneurop Cagi Test Code" – Insertion of Hand vibration meter
Vibration Reduction (Jain A. R. Tony et al., 2021).	Design & Fabrication Design to Reduction of Vibration discomfort.
Vibration absorptions (Johnson et al., 2017).	Design and fabrication of attachment to Reduction of harmful vibrations.
Operator grip relief. (Antonucci et al., 2017)	Reduction of tools weight to reduce of muscle activity during lifting.
Vibration extent (Brismar T, Ekenvall L., 1992)	Bit wearing to measure vibration extent.
Exposure reduction. (Mikhaltchouk and Forsman, 2021)	Tools selection - standardized laboratory protocol for Exposure reduction.
Vibration exposure assessment. (Gibb et al., 2015)	Calibrating Tools and Weightings and metrics to reduce vibrations.
Vibration measurement. (Bast-Pettersen et al., 2017)	Micro accelerator modelling for vibration reduction
Handle vibration and productivity (Rwamamara and Simonsson, 2012)	Robotic test bench force of application for Vibration reduction.
Health risk reduction. (Rempel and Barr, 2015)	Pneumatic rig development for high risk Vibration reduction.
Vibration evaluation. (Coggins et al., 2010)	Real time Vibration measurement.
Vibration reduction/ control (Paul S. et al., 1997)	Vibration Source oriented solution.
Work environment sustainability (Rwamamara and Simonsson, 2012)	Self-compacting concrete

The Current Knowledge With Regard to Mitigating and Reducing HAVS in the Construction Industry

The construction industry faces significant Hand-Arm Vibration Syndrome (HAVS) risks, particularly among workers exposed to vibrations from various tools and machinery. In 2019, over 1.6 million U.S. workers, including cement masons and electricians, were affected, leading to a rise in musculoskeletal disorders (U.S. BLS, 2019; Botti et al., 2020; Rwamamara and Simonsson, 2012). This issue is particularly pronounced in developing African nations, where monitoring and research on HAVS are inadequate despite the industry's substantial workforce and financial investment.

Implementing preventive measures is crucial to mitigate HAVS. Strategies include modifying processes to reduce vibration exposure, enhancing awareness through training programs, and utilizing low-vibration tools (Lewis et al., 2023; Bodley et al., 2015; Rempel et al., 2019). Anti-vibration gloves can also help, depending on their type and usage conditions (Clemm et al., 2022). However, existing prevention strategies often lack coherence, focusing narrowly on specific tools rather than a comprehensive approach. Future research should prioritize assessing HAVS prevalence in developing regions and adapting control measures accordingly (Bast-Pettersen et al., 2017). Improved data collection and understanding of site organization are essential for enhancing safety and minimizing exposure levels (Edwards et al., 2020).

CONCLUSION

Hand-Arm Vibration Syndrome (HAVS) is prevalent in the construction industry, with over 50% of workers affected, yet research is lacking, particularly in tropical regions (Su et al., 2013b). Most studies focus on the medical aspects of mining and forestry, neglecting construction workers, especially in developing countries like Africa. Current literature lacks a cohesive prevention framework, primarily addressing symptomatology and exposure limits. Preventive measures like vibration gloves exist, but task alterations face managerial challenges. High-cost calibrated equipment is rarely recommended. Further research is essential to understand HAVS in developing countries and to tailor control measures to local contexts (Bast-Pettersen et al., 2017).

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