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Ergonomic risk factors analysis for digitalizing work content and improving mechanic resilience in automobile repair workshops

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Abstract

Ergonomic risk factors predispose the auto-mechanic to insidious adversities, immolating resilient capability. Relatedly, tasks in automotive workshops in Nigeria necessitate varied involvement of human activities, technical skills and materials which impose different ergonomic problems. This paper evaluated the ergonomic risk factors in automobile repair workshops and prescribed new digital technology tips for remedial solutions. The methodology involved questionnaires, audit of work postures, inspection and pooled analysis of ergonomic risk factors following rapid entire body assessment standards. Results obtained indicate that in Nigeria, automobile maintenance still has high heat and musculoskeletal disorders (MSDs) burdens; auto-mechanics, likely out of ignorance, adopt work postures that raise their vulnerability to MSDs; and the neck, lower back and upper back were the most affected body parts. Integrating digital technology into maintenance procedures will reduce the risks of MSDs and prioritize continuous resilient performance. These findings will provide helpful information to policymakers and ergonomists to develop automobile maintenance safety ethics and MSDs condition prevention guides.

1. INTRODUCTION

Maintaining a product, including a motor vehicle, is the foundation of the after-sales quality assurance practices undertaken for a sustainable client-customer relationship. The implications of these quality assurance practices include establishing contacts and interaction points with customers, which produce a positive trust that works as a key factor for work relationship continuity (Hong et al, 2020). In Nigeria, the automotive maintenance sector is important to the economy because it provides direct and indirect employment to at least 40 % of the population (Afolabi et al., 2021). Also, the maintainability attribute of a product is one of the technical quality criteria used to improve product performance, which increases product availability and reliability (Nwanya et al., 2017). Furthermore, the automobile repair personnel, referred here to as auto-mechanics or operators, are relevant to the transport sector because, due to their ingenious efforts, the growing numbers of second-hand cars in Nigeria are roadworthy (Afolabi et al., 2021). The number of small-scale or informal automotive maintenance firms is about 4.2 million members in Nigeria, with a turnover of about 3 billion annually (Nwankwojioke et al., 2017). The mechanics' services are continuously in high demand because fairly used motor vehicles (locally referred to as "Tokunbo" vehicles) require regular maintenance due to vehicle age, and most roads are in bad condition (Ojo et al., 2017). The foregoing statements have also depicted the repair of automobile vehicles as a socio-technical or a poly-work system, whereby a large number of varied operations are made, and materials flow from different processes en route to the same vehicle. In addition, automobile repair tasks comprise vehicle bodywork, painting, electrical repairs, engine dismantling, pressing and parts assembly work systems. These require huge ergonomic considerations to animate the different materials and job content flows.

In this paper, the automotive repair workshops were evaluated from the perspective of a poly-work system. This is interesting for a Nigerian scenario because it helped to expose the preponderance of ergonomic risk factors associated with tasks constituting such a socio-technical work system. In a sense, automobile mechanics suffer from daily ergonomic risk factors affecting their task performance cycle and efforts to cultivate safe work habits. As they relate to ergonomics, risk factors increase the chances of negative results (Ukoha, 2022). Basic risk factors in automobile repair job shops include work repetition, awkward posture, and forceful exertion (OSHA, 2018; OEM, 2018). In recent times, there has been an exponential rise in the trend of cases of ergonomic risk factor problems in automobile workshops in Nigeria. The reasons are that the repair jobs are highly labour intensive, artisanal, and force-demanding due to awkward posture, and they are predominantly carried out in an inclement open space. Consequently, in these situations, the auto-mechanics are exposed to strenuous postures (Vyas et al., 2011), improvised tools and machinery as well as poor psycho-social environments, which all together exert undue influence on their health and safety (PubMed, 2011), sometimes lead to musculoskeletal disorders. In Nigeria, there is no evidence of safe work habits or the use of devices to proactively detect and innovatively ameliorate occupational hazards and risks with a supportive digital technology (DT) by the automobile workshop workers. A DT refers to an interfaced device or package containing either a complete measurement device or a component integrated into a measurement system (MS) with a digital processor that can monitor and detect ergonomic risk factors within the vicinity of the auto-job shop in question. These deficit features correctly reflect the current situation of automobile maintenance in Nigeria.

A glimpse into the extant literature revealed different approaches previously adopted by various authors concerning some of the raised problems. Anyaeche and Ishie (2016) only assessed risk factors for musculoskeletal disorders in small-scale one-line auto repair shops. Afolabi et al. (2021) explored the artisans' perception of the causes and possible barriers to preventing OSH problems. Osinaike and Oke (2018) utilized the quantitative risk analysis method and the expected monetary value of the various hazards to calculate the adverse financial impact associated with the highest-priority risks. Further useful insights into the prevalence, pattern and severity of ergonomic risks among automotive maintenance mechanics in Nigeria could be obtained from the following literature: Abaraogu et al., (2016), Adedotun et al. (2022) and Nwankwojioke et al. (2017).

Findings from those studies in the literature so far showed that little attention has been paid to MSDs among automobile mechanics. Also, the implications of these ergonomic risk factors on the mechanic's strength or resilient productivity were neither adequately investigated nor empirically analyzed. To the best of the authors' knowledge, no work in the extant literature has advocated digitalization of work contents as ergonomic risk relief and resilience improvement measures for automobile repair and servicing in Nigeria. The foregoing revealed gaps as the justification for the current article. Hence, this study hopes to close the gaps by ergonomic evaluation of selected automobile repair workshops to uncover the occurrence of self-reported MSDs among workers. The results of this study will provide background information to future researchers.

To this end, the current study aimed to evaluate ergonomic risk factors in automobile repair workshops and prescribed digital technology tips for work improvements. The specific objectives of this paper include identifying ergonomic risk factors in the automobile repair workshop in Nigeria, analyze the impact of some of the ergonomic risks on automobile workshop workers or auto-mechanics, suggesting available DT strategies for the automotive job shops to improve performance and relieve risks or musculoskeletal disorders (MSDs) during different operations.

This study is significant since it advocates that occupational risks and workshop injuries can be reduced through awareness. Arguably, the improvement of automobile workshops is extendable to the use of DT interface between maintenance operators and workstations.

2. METHODOLOGY

For clarity regarding the purpose of this research study, the methodology was described based on the following points: sample selection, data collection instruments, and Rapid Entire Body Assessment (REBA). The study sample space was 44 out of the 50 population in three independent workshops, and a pooled analysis of the population data was used.

2.1 Sample selection of case study workshop

Data for this study were collected using a qualitative method from three selected medium-scale or standard automotive maintenance workshops. The result from a qualitative strategy is deemed subjective. Hence, evaluation is necessary to prove the preponderance of inherent risk factors as experienced in the case study of automobile repair workshops. The automobile workshops are located in Abuja, the federal capital of Nigeria, and, for confidentiality reasons, were referred to as Workshop A, Workshop B and Workshop C. The choice of Abuja was influenced by the inhabitants' lifestyle, which depicts the ability to pay for standardized auto-maintenance service charges, and it added diversity to the extant literature on the subject.

The term standard automobile workshop, used in describing the selected repair shops, indicated the expected tools and expertise of mechanics and automotive vehicle jobs to be carried out. The inclusion criteria for selection of each workshop were the availability of the following tools: air compressor, jack, jack stands and pole jacks, oil drain, battery charger and jumper, engine hoist, brake lathe, air conditioning machine, press, transmission jack, vehicle lifts and pits, forklift, rolling tool boxes, power wrenches and some other special tools (peculiar to the different brands of vehicles in the workshop). These were found available for technicians at each selected workshop site.

2.2 Instruments for data collection and analysis

The following instruments, questionnaires, interviews, and inspections were used, and inclusion criteria for the participating automobile mechanics were at least one year of certified experience with no gender restriction. On experience, they met that criterion before employment at the workshops. For a walk-through inspection segment, the purpose was to identify ergonomic risk factors in situ due to improper practices and design of the workstations. The automobile mechanics at work were observed and captured, using a FujiFilm FinePix A850-8MP digital camera, while carrying out their tasks in the workshop. Apart from their work postures, other physical and ergonomic risk factors were observed and evaluated as stressors in the workshop. Also, oral interviews were granted to senior technicians in the workshops.

The initial questionnaire was appraised, and some sociodemographic items like age, weight, height, duration of work hours, on-the-job experience and use of protective equipment were included during the walk-through inspection. Then, the final or improved version of the questionnaires was distributed to mechanics in those workshops, and responses were retrieved. The validity of the final questionnaire was confirmed by the positive response from 88% of the 50 workers in the selected three workshops. In addition to the demographic segment, the MSDs screening segment of the questionnaire focused on body part symptoms and the sources of injury or discomfort. The purpose of the symptom survey was to document whether there were trends in the pain, discomfort and injuries among technicians in the workshops. The data collected through observation, interviews, and questionnaires were arranged in Microsoft Excel and then analyzed using correlation statistical methods, and results were retrieved.

2.3 Postural risk assessment using REBA

The postures captured in pictures were analyzed using REBA method. The REBA was developed by Werner et al. (1997) as a means to assess entire body posture for risk of work-related musculoskeletal disorders (WRMSDs). The REBA worksheet was divided into two body segment sections labeled A and B. Section A covers the neck, trunk, and leg. Section B covers the arm and wrist. This segmenting of the worksheet ensures that any awkward or constrained postures of the neck, trunk or legs that might influence the arms and wrist postures are included in the assessment. To determine body risks based on REBA, a score value was assigned only for each of the body regions involved in awkward posture, in accordance with Hignett and McAtamney (1999). Then, the values for each body region were collated from the first row to the last row and used to compile the risk factor variables, later summed to generate a single score value that represents the level of MSD risk. The pictures are not displayed in this paper to protect the privacy of the mechanics captured in awkward postures. The study duration implied the period that data were collected at the workshops, which was 12 months.

3. RESULTS AND DISCUSSION

In all three visited workshops, salient ancillary workshop facilities were observed, such as standard adjustable overhead lifts and pits made from cement with in-built ladders/steps, which allowed the workers to work from different levels concerning their heights. It was also observed that the workers operate for eight (8) hours with one hour break period per day. Also, the weights and ages of the auto-mechanics fell between 50- 80 kg and 15 – 60 years, respectively. Essentially, these sociodemographic data were used for health reasons to determine trends of the MSDs impact on auto-mechanics and measure how susceptible to underweight and locomotor function loss risks the operators can be in work-related conditions. Also, this study observed that auto-mechanics mostly worked standing on hard floors made of cement or equivalent surfaces. Torp et al. (1996) stated in an earlier work that people who continuously stand while working are more likely to suffer from pain and aching in the legs and lower back than others.

In workshop-by-shop cross-sectional analysis, the most frequently carried out tasks include general vehicle servicing, brake pad change, suspension system repairs, electric fault repairs, engine dismantling, and service. The frequency of each operation is shown in Figure 1. Other sources of discomfort were using manual tools, manually lifting heavy weights, wearing safety shoes for long hours and inadequate rest periods between tasks. This type of information is useful for preventive work against MSDs.

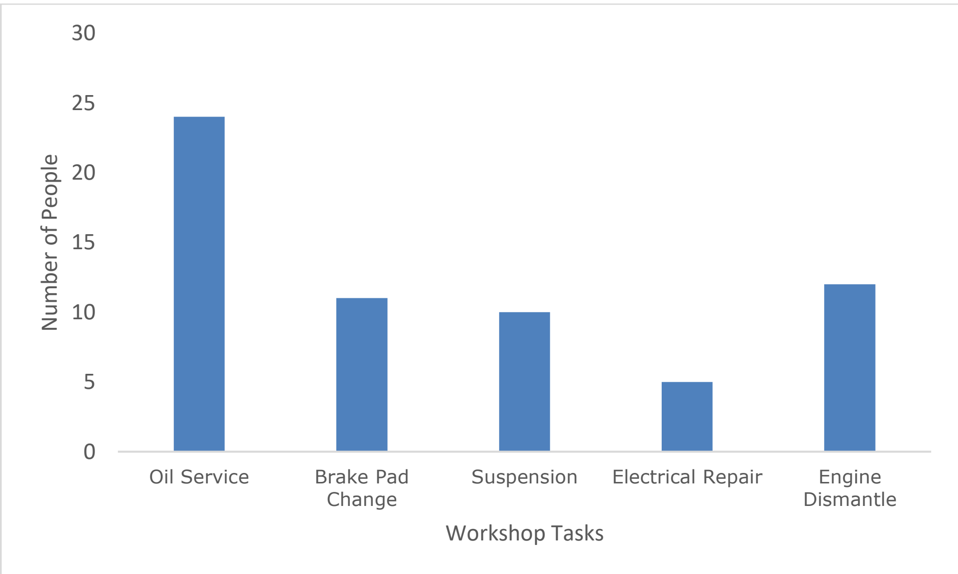

Figure 1. Frequently carried out tasks

In all the Workshops, the respondents had experienced body discomfort at the neck, shoulders, wrists, upper back, lower back, hips/thighs/buttocks and ankle/feet within the 12-month period. Figure 2 shows a summary of the three workshops' frequency of workers incapacitation as it affects body parts in 12 months. Work-related injury/discomfort incapacitates a worker if it renders the worker unfit for normal functions for more than 12 hours. The neck was the body part that experienced the most discomfort, as shown in Figure 2. The lower back and the upper back followed this.

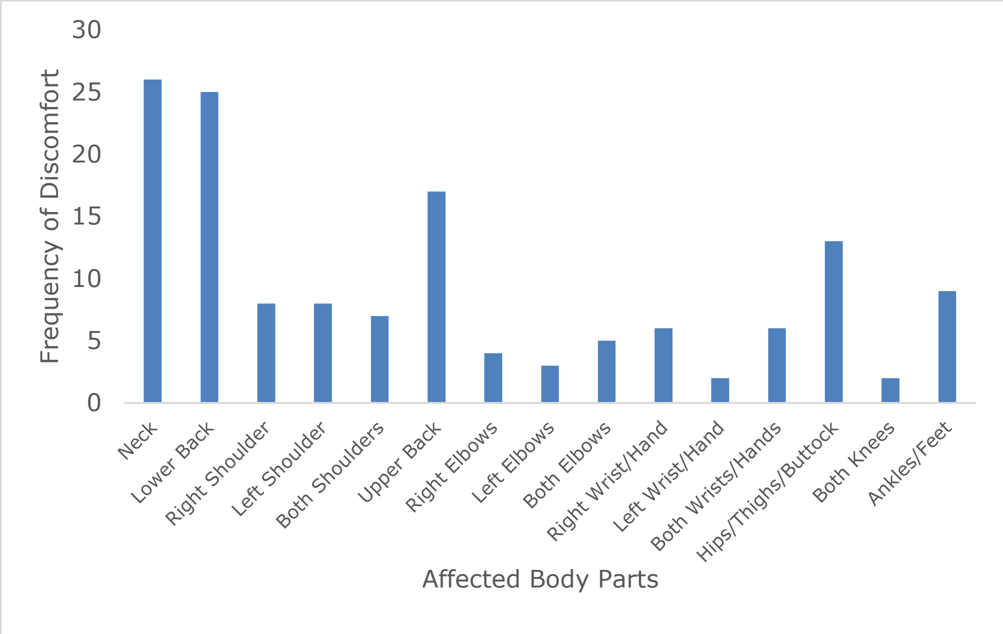

Figure 2. Frequency of incapacitated workers concerning body parts

Analysis of results for the total number of incapacitated workers concerning their ages was carried out. Figure 3 shows the trend of the results of the survey with respect to their ages and body parts. Across the workshops, all the respondents were categorized into age ranges of 15 – 25 years, 26 – 35 years and 36 – 60 years.

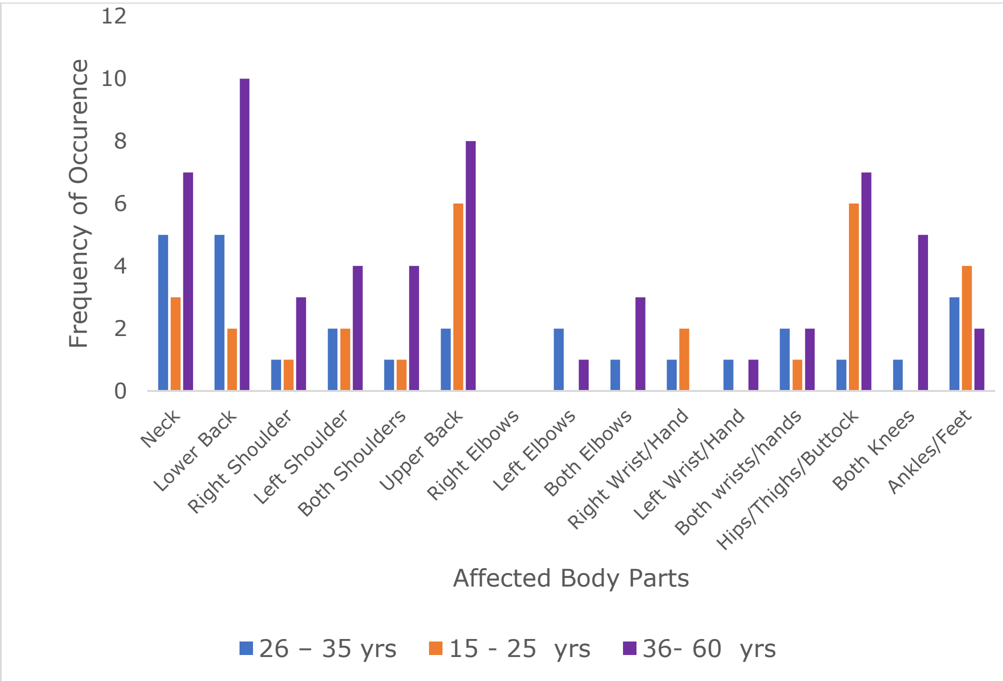

Figure 3. Frequency of occurrence of incapacitation in workers concerning their age

Body weight was another item evaluated concerning work-related musculoskeletal disorders. Across the workshops the respondents were categorized by body weights: 50-70 kg and 71 -100 kg. Figure 4 represents the frequency distribution of the incapacitated auto-mechanics with respect to their weights. The weight category 50-70 kg across the workshops recorded the highest level of incapacitating discomfort within the upper back period and disorder, which was the highest, closely followed by hips/thighs/buttocks. For weight category 71-100 kg, there were low incidences. However, the trend of the impact on body parts in the 50 – 70 category almost repeated itself in the 71 – 100kg category. Thus, implies that body weight is a significant indicator for management of musculoskeletal disorders, especially when used in body mass index estimation.

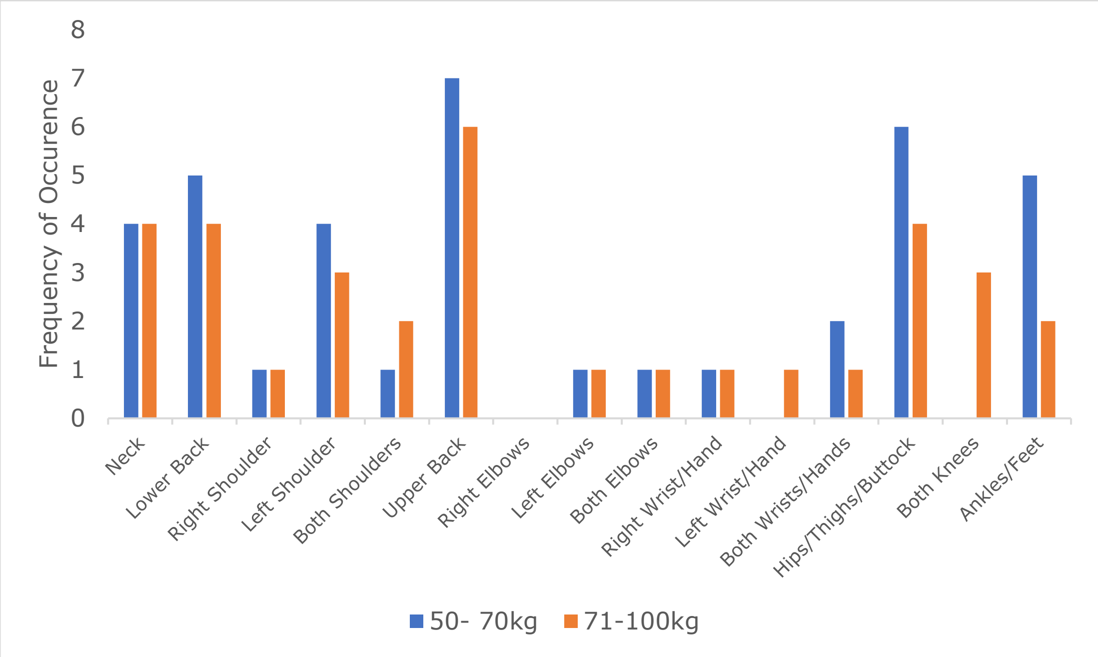

Figure 4. Frequency of occurrence of incapacitation in workers with respect to their weight

Furthermore, analysis of posture assessment using REBA was conducted in the three workshops, and vehicle service was the most frequently carried out task. The postures adopted during vehicle services were standing while working under the vehicle (either with the vehicle raised on a lift or the technician standing in the pit), bending at the side or in front of the vehicle and working inside the vehicle.

Therefore, the under-listed ergonomic issues were found to be common in all the visited workshops:

- Many of the workers' tasks required force, awkward joint positions and repetitions that continued for over 30 minutes at a time.
- Most of the tasks could not be performed without bending, twisting or turning their backs or necks.
- To carry out the tasks, the workers had to reach out with their shoulder(s), forearm and wrist in uncomfortable positions (i.e. bent or twisted).
- Sometimes, the workers could not vary their postures until the end of the tasks at hand.
- For workers using powered equipment, no personal protective equipment (PPE) to protect them against noticeable risk factors in the job shops.

Using the REBA tool, the pictures taken in the various workshops were assessed for the level of MSD risk. The following postures were assessed and discussed: working under the vehicle (with the vehicle raised), bending while working at the side of the vehicle, bending while working at the front of the vehicle, bending while working on the wheel of the vehicle, squatting while working on the wheel of the vehicle, sitting while working on the wheel of the vehicle, and twisting while working inside the vehicle.

For a general discussion on and comparison of the findings in this study, the work based on workplace health and safety by Queensland, Department of Justice and Attorney-General was selected for a constructive debate. All these findings in the study form part of the parameters used in identifying hazards in the automobile service and repair industry. Arguably, thus, they would have played major roles in the musculoskeletal symptoms (MSS) evident among the workers in the three workshops. From this study, risk factors for MSD in automobile maintenance include tasks that need a lot of power and exertion, lifting, awkward work postures and prolonged tasks, and there were similarities between these trends in the works done by Onawumi et al. (2022), Omokhodion and Osungbade (1996), and Sambo et al. (2023). These strenuous tasks increase metabolic heat production, which increases core temperature (Neal et al., 2024). Across the workshops, there was zero percent female auto-mechanics, which likely implies that more strength is required for daily activities, predisposing auto-mechanics to age faster. Onawumi et al. (2022) made a similar observation. Again, findings from this study showed the neck, lower back, and upper back were the most affected body parts, and these results aligned with Sambo et al. (2012), and HSE, 2019).

Further relating the revelation from the study to extant literature, some of the results were in disagreement with the work conducted by Sambo et al. (2012), which reported that most of the automobile workshops in Nigeria do not have any personal protective equipment in place to protect their workers. But, the site visits revealed otherwise. The disagreement in the findings can be attributed to increased ergonomic awareness within the time interval between the studies. Many of the workers interviewed admitted being provided with personal protective equipment (at least the basic ones, e.g. safety boots, hand gloves and goggles). Under interrogation, it was discovered that they were not using them for either inconvenience or hindrance to achieving their intended speed while carrying out their daily activities. Also, some of the provided job aids such as hoists, cranes, power tools, and adjustable work benches were only being used by a few of the workers while the rest engaged in manual means to carry out their tasks. This attitude towards some of the provided safety measures could be attributed to their ignorance of possible actions that could lead to injuries in the auto workshops. Arguably, the workshops do need a lot of catch-up in ergonomic or human factors practice, which is still below standard both in work design and training schemes offered to workers, and this, in turn, explains why the prevalence of workplace hazards and MSDs are on the increase.

Table 1 summarized the discussed posture assessment results with implications on automobile workers. In Table 1, these data breathe the life of quantity into inert situations in the visited automotive workshops. The essence is that human factors and ergonomic experts who act on their first reaction to these data can readily determine a mathematical function that describes the probability of the incident variations and represent the totality in reality.

Regarding the high prevalence of lower back pain among the workers, viewed from the combined results of the questionnaires and the REBA scores, it can be a consequence of the combined effects of strenuous activities in the workshops (such as forceful exertions and manual lifting of automobile components parts) as well as the awkward postures commonly adopted at work by workers. In addition, Adeyemi (2016) reported that forward bending patterns required by the tasks might also have contributed to the high degree of lower back pain among these groups of workers. Thus, the findings from this study have been discussed to evolve suitable relief measures.

Table 1. Summary of REBA assessment of the postures and possible implications

S/N	Activity/constraint	REBA score	Remark	Implications
1	Working under the vehicle (with the vehicle raised)	10	High risk; investigate and implement change	This posture can cause MSD if no change is implemented.
2	Bending while working at the side of the vehicle.	11	Very high risk; implement change now	This posture has a high tendency of causing MSD if no change is implemented immediately.
3	Bending while working at the front of the vehicle	12	Very high risk; implement change now	This posture can lead to very high risk of MSD if changes are not affected immediately.
4	Bending while working on the wheel of the vehicle	11	Very high risk; implement change now	This posture can lead to very high risk of MSD if changes are not affected immediately.
5	Squatting while working on the wheel of the vehicle	12	Very high risk; implement change now	Very high risk of MSD is expected if changes are not affected immediately.
6	Sitting while working on the wheel of the vehicle	10	High risk; investigate and implement change	A high risk of MSD was expected if no change is implemented.
7	Twisting while working inside the vehicle	15	Very high risk; implement change now	A very high risk of MSD is projected if change is not affected.

The necessity for deploying DT in automotive repair services is due to the increasing number of reports of ergonomic adversities, as shown in Table 1. According to Nwanya and Achebe (2023), there is a relationship between the ergonomic risk factors in Table 1 and possibility of risks of musculoskeletal disorders, burnout and insidious death due to the automobile operators. Thus, the future of automobile maintenance depends much on adept control of the ever-increasing associated ergonomic risks of musculoskeletal disorders and improving efficiency and swift decision–making in the automobile job shop. The aforementioned dependent benefits are technology driven, and the sector's digitalization guarantees solutions. It has been observed that digitalization is a competitive asset in the industrial automotive industry because of societal changes and increasing competition among auto-manufacturing firms (Oliveira and Novikau, 2022), but the case is different in the maintenance.

Although the industry has various operations for digitization, this study advocates for digitalization of the automotive repair service value chain in Nigeria. Digitalization will allow new business models to develop customized insurance contracts, remote diagnostics and repair, and predictive maintenance services (Thomsen, 2022). Also, DT is needed to support auto-mechanics to monitor, self-adjust and provide solutions to the change from neutral posture to awkward posture while performing activity. This section of the current study explores opportunities to eliminate risks in repetitive, stressful and ergonomically disadvantageous tasks. It prioritizes continuous resilient performance if DT is implemented for automotive maintenance. Findings in Table 1 have provided a formidable basis for this study to discuss the choice of digital technology and digital solutions that can support or relieve strains of repetitive tasks for automotive repair mechanics.

The foregoing discussion has described the penetration of DT in automotive repair services as ideally anticipated remedy for handling strenuous manual activities such as lifting, postural, gripping and picking at awkward positions. The dynamic performance attributes of DT will enable it to adapt to the change in ergonomic (mental and physical) characteristics, knowledge, behavior, and habits of a mechanic to ensure the disruption of MSDs that cause activity. A DT measurement system can achieve the above-stated levels of performance because the output is in digital form, and it can be interfaced directly to a computer during ergonomic applications in an automotive repair service to give audio or visual indication of the magnitude of the ergonomic risk factors in question. During the interfacing, a universal serial bus (USB) protocol is required for communication between the device and a computer. Such DT devices include smart sensors, persuasive technology, and intelligent or smart transmitters.

The working conditions in which the DT will operate are another important consideration when choosing DT. Oftentimes, the mechanic is exposed to mechanical shock and vibrations. Then, piezoelectric transducers/sensors applications are good, especially when displacement needs to be translated into voltage. Photonic sensors can be used to modulate light intensity, and the light varies according to the mechanical deformation caused by pressure. In work conditions requiring kneeling, squatting, and twisting (as shown in Table 1), Photonic sensors can be applied to indicate pressure exerted by awkward posture and disrupt the action by distressing the audio mechanism. For long hours of standing and bending while working, persuasive technology devices can assist auto-mechanics in monitoring, self-adjusting, and controlling the situation by visual display of strain graphics sustained over the period. Through these functions, the DT can help improve automobile mechanics' work contents and performance resilience.

5. CONCLUSIONS

This study found a high prevalence of musculoskeletal disorders (MSDs) among teachers in Pokhara, with 71% reporting pain, especially in the lower back, shoulders, and ankles/feet. Female teachers and those with sleep disturbances were more likely to report MSDs. These findings highlight the need for ergonomic interventions, such as better seating and regular breaks, as well as policies to improve teacher health through wellness programs. Addressing both physical and behavioral factors can reduce MSDs, improve teacher well-being, and enhance job satisfaction and retention. Further research on effective interventions is recommended.

Based on the automobile workshops studied in the 12 months at Abuja, this study identified some ergonomic risk factors recognized some of the sources of injury and the discomfort level on various body parts of the workers during different operations. It also identified some of the symptoms that the mechanics regarded as the most troublesome (i.e., incapacitating) at work. It detected some exposure to ergonomic risk factors for several tasks. Even though it was unable to suggest alternative postures for the various tasks considered, it was able to suggest ways to prevent/reduce these risks, thus reducing occupational hazards/injuries and, in turn, reducing absenteeism while increasing productivity. For a sustainable way out of the situation, this study advocates for the digitalization of the automotive repair service value chain in Nigeria.

These results support the debate that rising cases of stressful work life among automotive job shop operators are linked to work posture. Based on this study, it can be said that the degree of pain that the workers were susceptible to increased with their body weight. As their body weights increased, so did their discomfort level and the degree of incapacitation, confirming earlier statements by the Occupational Safety and Health Administration, U.S. Department that "weight, height, body mass index (B.M.I.) and obesity have all been identified in studies as potential risk factors for certain MSDs as cited.

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