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Cardiovascular Strain of Sawmill Workers in South-Western Nigeria

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This study aimed to assess cardiovascular strain during sawmilling operations in terms of physical workload, based on heart rate changes. We measured resting and working heart rates and calculated cardiovascular load (%CVL), cardiovascular strain (%CVS) and relative heart rate (%RHR) in 35 sawmill workers. Based on heart rate only, the work in sawmills was classified as very heavy *and* extremely heavy. *Similarly, a high-level category was recorded for %CVL and a very high range for %CVS. Thus, the workload in sawmill operations is usually very high and can lead to physiological strain of the workers. There is a need to redesign the work content of this occupation to prevent excessive strain in the workers, as this will increase their productivity and reduce their health risk.*

cardiovascular strain cardiovascular load workload energy expenditure sawmill worker

1. INTRODUCTION

According to data from the Workers Compensation Board of Alberta for 1997–2002, there was a high rate of musculoskeletal injuries in the sawmill industry of Alberta, Canada [1]. These injuries could result from incidents like being caught in or struck by machinery, falling from a height, heavy lifting or repetitive movements, twisting or reaching, and breathing in noxious or toxic chemicals while working to increase productivity [2]. In 2003, the Workers Compensation Board reviewed the claims in the sawmill industry in Alberta, which showed that musculoskeletal injuries accounted for 32% of total claims cost (~2 842 851 USD) and 38% of total time loss (~13 600 days), i.e., more than any other injury category. Similarly, a higher percentage of bodily injuries was observed in a study conducted in Nigeria, which was attributed to lifting lumber, and lifting or lowering cut timber, boards and other heavy machine parts in awkward postures [2]. Simple forms of sawmilling operations have existed for hundreds of years, but in the past century there have been significant advances in sawmilling technology: introduction of electric-powered mills, improvements in saw designs and automation in sorting logs and other operations [3]. According to Uhumwangho, Njinaka, Edema, et al., some of these technologies are not available in developing countries, such as Nigeria, so manual processes are necessary [4].

Due to the high level of manual handling involved in sawmilling operations, the workers are exposed to higher levels of risk and high physical workload. Excessive physical workload and heat stress have been identified as factors that could result in sudden unexplained death syndrome [5].

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In Nigeria, as in most developing countries, labour cost is low and most work is done manually, so physical demands of the task often exceed the physical capabilities of the worker [6]. For work to be compatible with the worker and to enhance productivity, factors like physical capability, good health, absence of accidents and task performance are required [7]. One third of industrial back injuries could be reduced by designing the job to fit the worker [8]. There is, therefore, a need to evaluate the physiological workload of sawmill workers in Nigeria.

The aim of this study was to assess cardiovascular strain during sawmilling operations in terms of physical workload, based on heart rate. Heart rate is commonly used to estimate energy expenditure or physical strain during sports, work or daily activities [9, 10, 11].

2. METHODS

2.1. Participants

A group of 35 men, with a median (*SD*) age of 36.3 (4.2) years and height of 1.64 (0.09) m, participated in the study. They worked in four different sawmills in Eruwa, Oyo State, Nigeria. All participants were engaged in operations that involved strenuous manual activities, such as moving planks, and transporting, loading and offloading logs.

2.2. Informed Consent of Participants

A few days before the study, the participants were given adequate information about it. Their consent was obtained before the start of the study.

2.3. Measurements Protocol

The participants' heart rate was measured during habitual sawmilling operations and as such was not expected to be affected by the research. The measurements were made with a stadiometer for body height (metres), a digital sphygmomanometer (Polygon YS796; Polygon Direct, China) for heart rate (beats per minute, bpm) and a weighing machine for body mass (kilograms). The participants were allowed to rest sufficiently before starting the activity, to determine the resting heart rate (HR_{rest}) while they were lying on mattresses. The measurements were taken 3 times to ensure correctness; no changes were observed. The working heart rates (HR_{work}) were taken after the participants had worked continuously for 4 h at 30-min intervals. Heart rate was measured by holding the participant's left arm in front (with the palm facing up) and sliding the cuff onto the wrist, ensuring that the monitor was on the inside of the wrist, with the display in easy view. The cuff was comfortably wrapped around the wrist (with the top and bottom edges of the cuff tightened evenly around the wrist) and the power button was pressed. The participants were not allowed to talk or move during this period. The left elbow was held to ensure the participant did not move the hand during measurement. The reading was thereafter taken at ~1 min.

2.4. Determination of Physical Strain

Three ways of determining physical strain were used: relative cardiovascular load (%CVL), cardiovascular strain (%CVS) and relative heart rate (%RHR).

%CVL was evaluated on the basis of heart rate as follows [12, 13]:

$$\%CVL = 100\% \times [(HR_{work} - HR_{rest}) / HR_{max(8h)}], \quad (1)$$

where HR_{work} = mean heart rate in the job during various tasks, HR_{rest} = heart rate in a resting position, $HR_{max(8h)}$ = maximum acceptable heart rate for a work shift of 8 h, calculated as 1/3 × (220 – age) + HR_{rest}.

%CVL was used to evaluate cardiovascular load or aerobic strain: <30% = *acceptable level, no action required*; 30%–59% = *moderate level, peak loads should be reduced within a few weeks*; 60%–99% = *high level, peak loads should be reduced within a few months*; 100% = *intolerable high level, peak loads should be reduced immediately or work must be stopped*.

%CVS was calculated with Equation 2:

$$\%CVS = 100\% \times [(HR_{work} - HR_{rest}) / HR_{rest}], \quad (2)$$

where HR_{work} = mean working heart rate; HR_{rest} = resting heart rate.

Astrand and Rodahl's categories of work intensity were used to classify %CVS: *light* (HR_{work} < 90); *moderate* (90 ≤ HR_{work} < 110); *heavy* (110 ≤ HR_{work} < 130), *very heavy* (130 ≤ HR_{work} < 150) and *extremely heavy* (150 ≤ HR_{work} < 170). Consequently, %CVS was classified as follows: 0%–50% = *acceptable, no action required*; 51%–80% = *moderate, action required within a few months*; 81%–120% = *high, action required within a few weeks*; 121%–150% = *very high, action required within a few days* and 151%–180% = *intolerable, action required immediately* [14].

%RHR, which is also an indicator of physical workload related to muscular activities [15, 16], was computed with Equation 3:

$$\%RHR = (HR_{work} - HR_{rest}) / (HR_{max} - HR_{rest}), \quad (3)$$

where HR_{work} = mean working heart rate; HR_{rest} = resting heart rate; HR_{max} = predicted maximum heart rate, calculated as 220 – age [14].

2.5. Statistical Analysis

Statistical analysis was conducted with SPSS version 16.0.

3. RESULTS

Table 1 shows the basic statistics of anthropometric data obtained in the study, i.e., range, standard deviation, 5th percentile, median and 95th percentile. The participants' median age was 37 years (range: 29–46), median body height was 1.6 m (range: 1.5–1.8). Their median body mass index (BMI) was 24.2 (range: 20.1–31.1). Normal BMI is 18.5–24.9, while 35.0–39.9 is regarded as moderately obese [17], so none of the workers were underweight or more than slightly obese.

The median resting heart rate (HR_{rest}) was 68 bpm, compared to the median work heart rate (HR_{work}) of 158 bpm. The median predicted maximum heart rate (HR_{max}) was 183 bpm, while the median maximum acceptable heart rate for an 8-h work shift ($HR_{max(8h)}$) was 129 bpm. Standard deviations were higher for $HR_{max(8h)}$ (6.9) and HR_{rest} (6.1) than for HR_{work} (4.6) and HR_{max} (4.2).

Table 2 presents values of %CVL, %CVS and %RHR. The median value of %CVL was 69%, while that of %CVS was 106.3%, with a wide range of 105.3%–182.0%. The median %RHR was 77.9%.

4. DISCUSSION

Sawmill activities include moving planks; transporting, loading and offloading logs; and stacking, which involves a lot of lifting and working in awkward postures. The hazardous nature of the work is probably the reason for having many young men at the sawmills. The age range in this study was 29–46 years, implying that those who participated in milling activities were those in active age, who can meet the demands of the job [2]. These people also have the highest strength

TABLE 1. Anthropometric Data of Nigerian Sawmill Workers (*N* = 35) and Their Heart Rates (in Beats per Minute, bpm) Measured at Rest (HR_{rest}) and During Work (HR_{work}), Predicted Maximum Heart Rate (HR_{max}), and Maximum Acceptable Heart Rate for an 8-h Work Shift ($HR_{max(8h)}$)

Statistic	Age (years)	Body Height (m)	Body Mass (kg)	BMI (kg/m^2)	HR_{rest} (bpm)	HR_{work} (bpm)	HR_{max} (bpm)	$HR_{max(8h)}$ (bpm)
Range	29–46	1.5–1.8	58–75	20.1–31.1	56–76	148–168	174–191	116–140
5th percentile	29.7	1.5	58.7	20.3	57	150	178	117
Mdn	37.0	1.6	66.0	24.2	68	158	183	129
95th percentile	42.2	1.8	72.3	29.7	75	165	190	138
SD	4.2	0.1	4.3	3.0	6.1	4.6	4.2	6.9

Notes. BMI = body mass index; HR_{max} = predicted maximum heart rate, calculated as 220 – age [14]; $HR_{max(8h)}$ = maximum acceptable heart rate for a work shift of 8 h, calculated as 1/3 x (220 – age) + HR_{rest} [12, 13].

TABLE 2. Cardiovascular Load (%CVL), Cardiovascular Strain (%CVS) and Relative Heart Rate (%RHR) of Nigerian Sawmill Workers (*N* = 35)

Statistic	%CVL	%CVS	%RHR
Range	57.2–87.7	105.3–182.0	68.4–87.0
5th percentile	57.6	106.3	69.1
Mdn	69.0	130.4	77.9
95th percentile	85.5	173.8	84.0
SD	8.9	22.5	4.6

level [9]. Workers outside this age range were administrators, supervisors, drivers, or sawdust and shavings packers.

The median heart rate of 158 bpm, needed to do the work in sawmills, was over the recommended limit of 110 bpm for an 8-h work shift [18, 19]. The work in sawmills is between *very heavy* and *extremely heavy* according to Astrand and Rodahl's classification [14], since their working heart rates were 148–168 bpm. %CVL was between *moderate* and *high*, with a range of 57.2%–87.7%. However, on average the work belongs to the high-level category, with a median %CVL of 69%. According to Yoopat, Toicharoen, Glinsukon, et al., %CVL of 61%–100% represents high-level workload and action should be taken to reduce it as soon as possible [13]. Considering the median %CVS of 130.4%, on average the work belongs to the very high range, so action is required within a few days. Similarly, the median %RHR of 77.9% obtained in this study was higher than the 30% and 24.5% recommended by Shimaoka, Hiruta, Ono, et al. [20] and Wu and Wang [15], respectively. Similarly, according to Apud, Bostrand, Mobbs, et al., %RHR at work is an important indicator of physiological strain and should not exceed 40% for an 8-h period to avoid fatigue [21].

Thus, tasks can cause high cardiovascular strain during an 8-h workday and may cause fatigue and higher muscular strain in workers, with associated muscular pain. The workers had values over the recommended levels of cardiac strain indices; this shows that the activity caused high cardiovascular load on sawmillers during their work. The high cardiovascular load may be responsible for high percentage of bodily injuries recorded by Bello and Mijinyawa [2] and the high prevalence of eye injury observed by Uhumwangho, et al. in the sawmill industry [4].

5. CONCLUSIONS

The work content of sawmill workers in this study was usually above normal and posed a health risk to the workers. Therefore, it is necessary to redesign the working system of sawmill workers, to reduce cardiovascular strain and increase productivity. Additionally, lifting and motorized positioning devices should be provided to reduce the stress and energy expenditure involved in carrying loads.

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