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Ergonomic, Risk and Cardiovascular Strain Assessment of Building Construction Workers in Selected Areas in Southwestern Nigeria

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ABSTRACT

Building construction workers are exposed to high risk level of Musculoskeletal Disorders (MSDs) which have high negative effects on their health. This study aimed at appraising the ergonomics, risks and physical strain of workers during building construction activities in some selected sites in Oyo State, Nigeria. The study area covers 25 building construction sites in Ibadan, Ogbomoso and Oyo cities in Oyo State of Nigeria with total sample size of 251 construction workers. Relevant data were collected and Rapid Entire Body Assessment (REBA) was used to analyze the MSDs' data. Also, Body Mass Index (BMI), Relative Cardiovascular Load (% CVL), Cardiovascular Strain (% CVS) and work intensity were also determined. The REBA results show that over 93% male (both labourers and bricklayers) worked at very high risk level while 76.9% female labourers worked at high risk level. The BMI analysis shows that 21 of the workers are underweight. The minimum and maximum resting heart rates observed in female labourers and bricklayers are 49bpm and 93bpm, respectively. It was also observed that 92bpm was the minimum working heart rate in all workers and 151bpm was the maximum in bricklayers. More than 70% of the workers fell within the acceptable and medium range of %CVL and %CVS. However, work intensity classification showed that not less than 50% of men (labourers and bricklayers) experienced moderate work intensity while more than 63% of the female experienced heavy work intensity. Thus, relevant safety equipment should be made available for construction workers' use while awkward working posture and repetitive activities should be reduced by having a work shift plan.
Keywords: Musculoskeletal disorders, Physical strain, Body Mass Index, Cardiovascular, Heart Rates

Aims Research Journal Reference Format:
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1. INTRODUCTION

Buildings have been considered as one of the most valuable assets of a nation to provide people with shelter and facilities for work, leisure, prayer and, learning (Odimabo and Oduoza, 2013). Most construction projects cover a range of activities such as site clearance, demolition or dismantling of building structures or plant and equipment, the felling of trees and the safe disposal of waste materials (Aranda, 2012). Construction industry is one of the largest industries in most industrialized countries and currently one of the major drivers of economic growth and essential developmental factor both in developed and developing nations. It employs multiple cadres of labour ranging from casual to the management. Vitharana, et. al. (2015) stated that that construction of building stages involve surveying, planning, and designing to form a building facility for such structure to be ready for its purposes (Saiman, 2010). Construction activities are inherently hazardous to health and safety of employee due to working at height, underground, confined spaces, nearness to falling materials, unsafe manual material handlings, noise/vibration, dusts, fire and exposure to live cables.

However, the occupational accidents frequently occur either due to lack of knowledge, carelessness, nature of work itself, over-exertion and being struck by an object while falling from a height causes most of the fatalities (Saiman, 2010; Alinaitwe et. al., 2007; Adebiyi, et. al., 2009; Cesarini et. al., 2013 and Kadiri, 2014). These, inadvertently affect the economic efficiency of the industry. Globally, it is estimated that both direct and indirect costs of accidents magnitude amounted to about $13 billion annually and the medical bill of non-fatal injuries alone cost more than $1.36 billion per year (Mesafint et. al., 2013). Also, about 60,000 fatal accidents recorded in construction sector and a worker die due to accident in every ten minutes (Yilmaz, 2014).

In Nigeria, construction work is regarded as the most hazardous industrial activities, having its rates of injury, harm and even death due to accidents on construction higher than other industries (Odimabo and Oduoza, 2013; Kadiri, 2014 and Phoya, 2012). Some causes of hazard in building construction includes; working on the ladder/scaffold, casting of beams or lintel, welding, excavation and unavoidable awkward working posture, poor safety management which result in unsafe work methods and procedures and continual change of conditions from project to project (Anandhababu, 2014 and Hosseinia, 2013). Prevalent causes of occupational injuries and accidents among these workers have been further identified as ignorance, poverty, lack of safety training and information on the risk of health hazards at the workplace (Mesafint et. al., 2013).

Selvam A and Krithika (2007) stated that fatal accident arising from bamboo scaffold and working on platform have accounted for nearly half of the total number of fall- from –height. The frequency of fall is one of the most serious problems in construction industries (Ohdo et. al., 2011). The uses of ladders also contribute to severe injuries because they are readily available and inexpensive (Ohdo et. al., 2011and Hola, 2009). Despite the knowledge of the dangers of falls from ladders, there has being a significant increase in the number of casualties from ladder falls which resulted into broken limb, fracture and bruises on workers on sites (Selvam A and Krithika, 2007).

Musculoskeletal disorders (MSDs) are associated with four main risk factors which are undesirable force, duration, repetition and the adoption of static and awkward postures (Health and Safety Laboratory, 2001). Ismaila (2013) reported that low back pain, neck and shoulder pain are associated with unsuitable working postures, and that construction workers are frequently exposed to awkward work postures, physical demands and different types of diseases, accidents. It is further reported that Work related Musculoskeletal Disorders, (WMSDs) is one of the most common diseases on construction site, and that there is a high risk of injury in the single-handed and repetitive manual handling techniques of blocks heavier than 20 kilograms and effects of repetitive motions coupled with the performance of the same tasks are increased when awkward postures and forceful exertions are involved (Ismaila, 2013). Work related MSDs affect a wide variety of construction occupations and the incidence is considered higher in construction industry than in most of the other occupations (Rwamamara, 2010). Worldwide, these disorders are the most frequent occupational injury and the commonest cause of severe long-term pain and physical disability among workers (Ekpenyong and Inyang, (2014).

The importance of safety on construction sites and workers can never be over emphasized. Good safety programs would help in reducing injuries at construction sites and also minimize construction costs, increase productivity and profitability and more importantly it could save lives of workers and consequently contribute positively to construction industry and the nation as a whole(Rosli, 2008). Therefore, this work considered bricklayers and labourers as part of the building construction site workers and more work was also carried out to determine the level of MSDs and body mass indices of these workers.

2. METHODOLOGY

The research was conducted out in 25 building construction sites in Ibadan, Ogbomoso and Oyo cities in Oyo State, Nigeria. In this study, data were collected from 251 site workers which are labourers, and bricklayers. A structured questionnaire which has five sections was designed and administered in various construction sites visited. The sections are demographic details of respondent, construction operations and machineries used, operational hazard and safety practices on construction site, MSDs experienced by the respondent and health related issues. In addition to the questionnaire administered, personal interaction with the respondent in the study area, through visitation, oral interviews, observation and interaction on site were carefully done so as to get more detailed information on the subject matter. Sample size was two hundred and fifty one (251). The respondents were from all the ranges of employees in the field; skilled, semi-skill and unskilled workers.

Epidemiological data were collected using Nordic Musculoskeletal Questionnaire (Ajayeoba et. al., 2016). The heights and weights of the workers were also collected using standiometer and weighing scale, respectively, to determine their Body Mass Index (BMI). The Heart Rates (HR) of each worker were measured with the use of a digital sphygmomanometer. Resting Heart Rates (HR_r) of the workers were taking very early in the morning on getting to the site before building activities after taken enough rest and Working Heart Rates (HR_w) of the workers were also taken according to (Ismaila et. al. 2012 and Ismaila et. al. 2013). Visitation/observation, data vetting, personnel interview, physical participation and oral interview (especially for those who could not express themselves in written English) were also used in gathering the required information.

Ergonomic Assessment (Rapid Entire Body Assessment (REBA) Analysis)
Statistical Package for Social Sciences (SPSS version 21.0) was used in sorting and REBA, an ergonomic assessment tool, was used to determine the level of risk these workers have exposed themselves to. These were carried out using the method as described in (Ajayeoba et. al., 2016).

BMI determination: BMI was calculated using:

$$BMI = \frac{weight\ (kg)}{(height)^2(m^2)} \quad (1)$$

Physical strain determination: Physical strain was determined using relative cardiovascular load and cardiovascular strain according to (Ismaila et. al. 2013).

Relative Cardiovascular Load (% CVL) – Cardiovascular load was evaluated using:

$$\%CVL = 100\% \times \frac{HR_w - HR_r}{HR_{max(8hr)}} \quad (2)$$

Where

$$HR_{max(8h)} = maximum\ acceptable\ heart\ rate\ for\ a\ work\ shift\ of\ 8hr$$

$$= \frac{1}{2} \times (220 - age) + HR_r \quad (3)$$

It should be noted that the main building activities are being carried out within an average working hour of 8hours

Scoring:
<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.*

Cardiovascular Strain (% CVS):Cardiovascular strain was evaluated using

$$\%\ CVS = 100\% \times \frac{HR_w - HR_r}{HR_r} \quad (4)$$

Scoring:
% 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
151%–180% = intolerable, action required immediately

Work intensity classifications of %CVS are as follows:

Light – HR_w <90;
moderate – 90 ≤ HR_w < 110;
heavy – 110 ≤ HR_w < 130,
very heavy – 130 ≤ HR_w < 150 and
extremely heavy – 150 ≤ HR_w < 170.

3. RESULTS AND DISCUSSIONS

Demographic information: In this study, out of the 251 site workers assessed, 49.4 % (124) were bricklayers (which included the supervisors), 35.1 % (88) were male labourers, while 15.5 % (39) were female labourers. The male labourers are those involved in carrying of concrete, bricks and bags of cement, mixing of concrete and digging of ground while female labourers are those involved in carrying of concrete, bricks, bags of cement and fetching of water. Having lesser female in the building construction operations may be because the work is strenuous and energy consuming which may not be easy or friendly to females. Larger percentage of 34.3% (86 workers) and 25.3% (59 workers) fell between the age ranges of 25-34 and 35-44 years respectively. This implies that those who participate in construction works are in their active age and have the highest strength level to meet the demands of the job. Fifty seven (57), 174, and 12 workers had primary, secondary, and post-secondary school level of education respectively, while only eight (8) of the workers had no level of education. This may be that this type of work does not need any serious academic requirements.

Two hundred and twenty five (225) workers (89.6%) worked for an average of 8 hours while 15 workers (6%) worked above 8 hours per day. Also, 184 (73.3%), 44 (17.5 %) and only 2 (1%) workers worked for 6, 5 and 2days respectively in a week. These show that, most of the workers worked 8 hours/ 6 days a week. However, 98 out of 124 bricklayers (73%) have between 6 – 10 years of experience while 111 out of 127 labourers have between 1 – 5 years of experience. Other details on equipment and machineries, operational hazard and safety practices on construction site and health related issues from the questionnaire are shown in Table 1.

Ergonomics assessment: Construction work involves lifting of heavy loads and working in an awkward posture. 61.8 % of the workers assessed used to lift loads heavier than 23 kg and while 21.5 % of the workers sometimes used to lift loads heavier than 23 kg, which contributed to pains experienced in some parts of the body and other health issues as shown in Table 1.

Risk Levels of Musculoskeletal Disorders: Figures 1 – 8 show some awkward positions of the workers at work that were analyzed using REBA employee assessment worksheet. Scores A, B and C were determined and final REBA scores were obtained. The final analyses were then summarized in Table 2 and it shows that the risk level of most male labourers (82 workers (93.2%)) was at a very high risk, and there is need for them to take a break. This may due to the type of work they were subjected to like: digging, carrying of bags of cements of 50kg each, bricks, and very heavy concrete as shown in Figures 1 – 4, which led to pains in many parts of their body, as shown in Table 1. Thirty (30) female labourers (76.9%) were also exposed to high level of risk due to the work they carry out which is not as strenuous as that of their male counterpart, they only partake in fetching water, carrying of bricks and sand. Though more investigation is needed for more analysis, there is need for them to take a break to avoid unnecessary hazards. But 120 bricklayers (96.8%) were exposed to a very high risk due to the work they do which involve more of bending and twisting of waist, wrists and necks as they lay blocks, plaster, deck with concrete and casting of lintel, columns and pillars as shown in Figures 5 and 6. Figures 7 and 8 however, show some other areas the workers exposed themselves to risks by working at height without any safety gadgets and proper Personal Protective Equipment (PPE). This could be the reason that most of them reported to be having back, shoulder and wrist pains as shown in Table 1.

Table 1: Summary of Collected Data

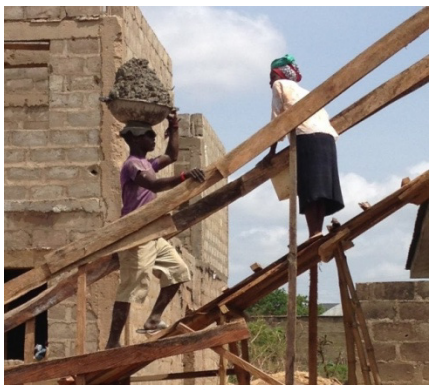
S/N	VARIABLES	FREQUENCY	%
1	How often they visit the hospital:		
	Often	16	6.4
	Very often	13	5.2
	Rarely often	135	53.8
	Not at all	87	34.7
2	The last time they visited the hospital (years):		
	Less than	33	13.1
	1-5	41	16.3
	6-10	51	20.3
	11-15	75	29.9
	16 above	51	20.3
3	The most dangerous and hazardous construction activity:		
	Digging	46	18.3
	Climbing	66	26.3
	Mixing/Parking of concrete	22	8.8
	Laying of blocks a lower level	14	5.6
	Laying of blocks a higher level	84	33.5
	Carrying of concrete using head pan	19	7.6
4	Equipment mostly used on construction sites:		
	Shovel	259	100
	Wheelbarrow	167	64.5
	Plum	175	67.6
	Head pan	259	100
	Hammer	89	34.4
	Hand trowel	259	100
	Line	4	1.5
	Mixer	1	0.4
5	How common does the equipment in 7 causes injuries:		
	Very common	18	7.2
	Common	34	13.5
	Rare	99	39.4
	Very rare	100	39.8
6	Musculoskeletal disorders or injuries of the job:		
	Bruises	10	4.0
	Joint dislocation	28	11.2
	Pain/strain	195	77.7
	Muscle cramp	12	4.8
	None	6	2.4
7	Most frequent accident encountered:		
	Fall from height	151	60.2
	Slip	56	22.3
	Equipment/ machineries accident	44	17.5
8	How often workers encounter accident:		
	Very often	8	3.2
	Often	33	13.1
	Rare	203	80.9
	Not at all	7	2.8
9	PPE used:		
	Safety boot	31	12.4
	None	220	87.6
10	Safety precautions usually carried out on site:		
	Safety awareness	193	76.9
	None	58	23.1

S/N	VARIABLES	FREQUENCY	%
11	Health challenges experienced due to work:		
	Headache	17	6.8
	Cough	9	3.6
	Body pain	135	53.8
	Skin infection	26	10.4
	General body weakness	55	21.9
	None	9	3.6
12	How often do you take drugs to meet up with work requirements:		
	Always	80	31.9
	Sometimes	35	13.1
	Rarely	19	7.6
	Not at all	119	47.4
13	If yes, how do they take them:		
	Hourly	1	0.4
	Daily	87	34.7
	Weekly	28	11.2
	Monthly	16	6.4
	None	119	47.4
14	Is the work environment safe and healthy:		
	Always	190	75.7
	Sometimes	49	19.5
	Rarely	12	4.8
15	How tired they were at the end of a working day:		
	A bit tired	116	46.2
	Tired	44	17.5
	Very tired	69	27.5
	Not tired	22	8.8
16	Medical problem or ailment due to work:		
	Chest pain	48	19.1
	Cough	24	9.6
	Skin infection	6	2.4
	None	173	68.9
17	Lifting, pulling or pushing a load above 23Kg:		
	Always	155	61.8
	Sometimes	54	21.5
	Rarely	31	12.4
	Not at all	11	4.4
18	Pains are experienced on the back:		
	Strongly disagree	2	0.8
	Disagree	20	8.0
	Agree	98	39.0
	Strongly agree	131	52.2
19	Pains are experienced on the Shoulder:		
	Strongly disagree	4	1.6
	Disagree	66	26.3
	Agree	82	32.7
	Strongly agree	99	39.4
20	Pains are experienced on the Neck:		
	Strongly disagree	1	0.4
	Disagree	104	41.4
	Agree	86	34.3
	Strongly agree	60	23.9

S/N	VARIABLES	FREQUENCY	%
21	Pains are experienced on the Arm:		
	Strongly disagree	1	0.4
	Disagree	39	15.5
	Agree	106	42.2
	Strongly agree	105	41.8
23	Pains are experienced on the Wrist:		
	Strongly disagree	1	0.4
	Disagree	58	23.1
	Agree	110	43.8
	Strongly agree	82	32.7
24	Pains are experienced on the Trunk:		
	Strongly disagree	1	0.4
	Disagree	50	19.9
	Agree	121	48.2
	Strongly agree	79	31.5
25	Pains are experienced on the Legs:		
	Strongly disagree	0	0
	Disagree	93	37.0
	Agree	72	28.7
	Strongly agree	86	34.3

Table 2: Summary of the Final Reba Scores

REBA Score	Level of Risk	Male Labourers		Female Labourers		Bricklayers	
		Frequency	%	Frequency	%	Frequency	%
1	Negligible risk	-	-	-	-	-	-
2 - 3	Low risk, change may be needed	-	-	-	-	-	-
4 - 7	Medium risk, further investigation, change soon	5	5.7	2	5.1	-	-
8 - 10	High risk, investigation and implement change	1	1.1	30	76.9	4	3.2
11+	Very high risk, implement change	82	93.2	7	18.0	120	96.8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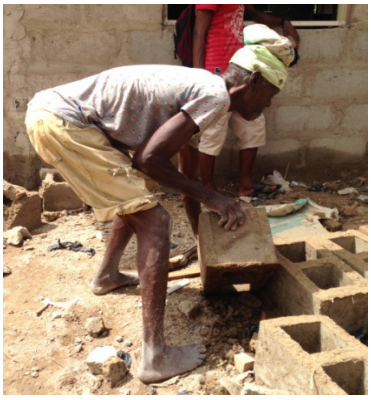
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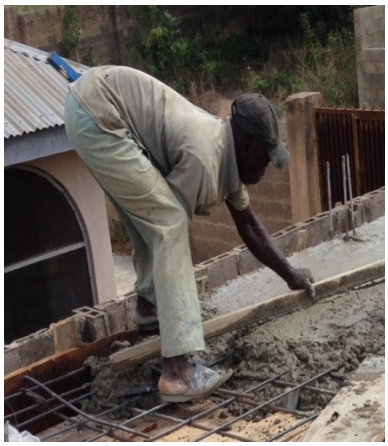
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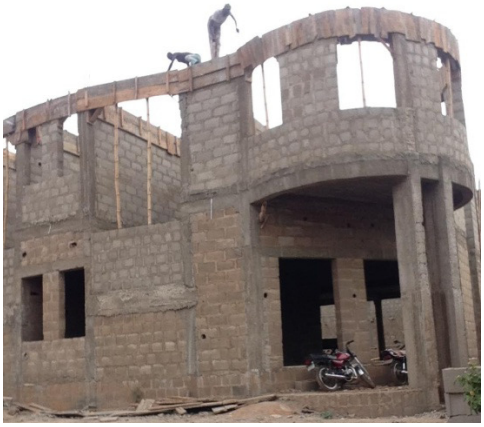
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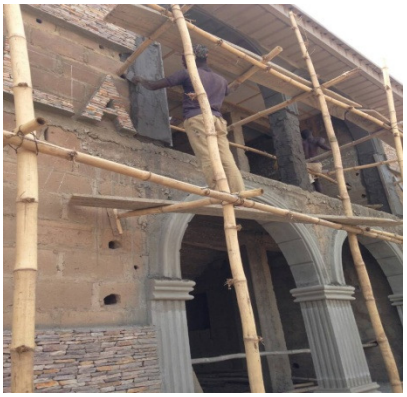
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Figures 1 – 4: Awkward working postures of labourers at work
Figures 5 – 8: Awkward working postures of bricklayers at work

Body Mass Index (BMI): As shown in Table 3, the average heights of the workers are 1.7, 1.6 and 1.7m for male labourers, female labourers and bricklayers respectively, while the average weights are 59.8, 61.3 and 63.7kg respectively. The results also show that the average BMI of the workers are 21.2, 23.9 and 22.1 kg/m^2 for male labourers, female labourers and bricklayers respectively. From the analysis, 21 of the workers were underweight, out of which 9, 1, and 11 are male labourers, female labourers and bricklayers respectively while most of the workers 75 male labourers, 28 female labourers and 95 bricklayers have normal weight. Likewise, only 4 male labourers, 5 female labourers and 3 bricklayers are overweight while none of the male labourers were obese but 5 female labourers and 3 bricklayers were obese. The strenuous nature of the job which makes it likely impossible for the workers to be overweight or obese may account for the high percentage of normal weighted workers.

Physical Strain of the Respondents: Table 4 shows the summary of the physical strain data collected. Forty nine (49) bpm was the minimum HR_r (experienced in the bricklayers) while 93bpm was the maximum HR_r seen in female labourers and bricklayers. The minimum HR_w was seen in male labourers, female labourers and bricklayers as 92bpm and 151bpm was the maximum HR_w seen in bricklayers.

Relative Cardiovascular Load (% CVL)
Thirty six (36), 14 and 44 male labourers, female labourers and bricklayers respectively have %CVL less 30% which is an acceptable level of CVL. Likewise, 52, 25 and 78 male labourers, female labourers and bricklayers respectively have %CVL between 30 – 59.9% which though it is a moderate level of CVL, yet the peak loads should be reduced within a few weeks. This is evident as most of the workers (73.3%) worked for an average of 8hr per day and 6 days a week. Also, only 2 bricklayers are within 60%–99% CVL, which is high level of CVL and peak loads, should be reduced within a few months.

Cardiovascular Strain (% CVS)

Furthermore, 22 male labourers, 10 female labourers and 2 bricklayers had % CVS within 0 – 50% which is an acceptable range and no action is required. Also, 47 male labourers, 17 female labourers and 76 bricklayers had % CVS within 51 – 80% which though it is a moderate level of CVS. 18 male labourers, 11 female labourers and

Table 3: Body Mass Index

Variables	Max			Min			Average			SD		
	ML	FL	B	ML	FL	B	ML	FL	B	ML	FL	B
Height (m)	1.8	1.8	1.9	1.5	1.4	1.5	1.7	1.6	1.7	0.1	0.1	0.1
Weight (kg)	84	82	94	47	39	44	59.8	61.3	63.7	7.2	9.9	8.9
BMI (kg/m^2)	28.2	35.3	36.7	16.8	17.0	16.6	21.2	23.9	22.1	2.2	4.3	3.1

Table 4: Physical Strain Data

	Age (years)			**HR_w (bpm)**			**HR_r (bpm)**			**%CVL**			**%CVS**		
	ML	**FL**	**B**	**ML**	**FL**	**B**	**ML**	**FL**	**B**	**ML**	**FL**	**B**	**ML**	**FL**	**B**
Max	70	51	65	140	143	151	86	93	93	56.0	60.4	70.4	128.0	128.3	137.9
Min	16	19	16	92	92	92	50	49	49	7.0	10.8	10.4	14.0	18.6	17.2
5th Percentile	17	20.9	23	93.4	92.9	93	52.4	52.8	52	18.0	16.4	20.0	33.0	31.2	34.5
50th Percentile	24	35	36	109	114	109	68	71	66	31.5	33.5	33.9	62.1	60.6	63.6
95th Percentile	52	43.5	57	129.3	132.6	137	84	89	92	49.3	47.2	45.9	102.3	94.1	90.7
Average	27.1	34.3	38	110.0	114.8	112	68.2	71.1	69	31.7	33.2	34.0	63.2	64.0	65.0
SD	10.2	7.6	10.7	11.7	13.1	13.5	9.2	11.2	11.3	9.3	10.6	9.6	20.7	23.0	20.6

Where ML = Male labourers, FL = female labourers and B = bricklayers

20 bricklayers had % CVS within 81 – 120% and are classified as high while only 1 male labourer, 1 female labourer and 3 bricklayers had % CVS within 121 – 150% and are classified as very high.

Work intensity

Work intensity classifications showed that none of the workers had working heart rates less than 90% meaning that none of the activities is light work. Forty six (46) male labourers, 14 female labourers and 63 bricklayers had working heart rates 90 – 109.9% and are classified under moderate work while 37 male labourers, 21 female labourers and 49 bricklayers had working heart rates within 110 – 129.9% and are classified under heavy work. But 5 male labourers, 4 female labourers and 11 bricklayers experienced very heavy work intensity (had working heart rates within 130 – 149.9%) and only 1 bricklayer had working heart rate of 151%, which is classified as extremely heavy.

4. CONCLUSIONS

Construction operations are strenuous and MSDs arise on daily basis due to repetitive activities and awkward working posture. Accident occurrence is rare, but the most common is fall from height. Virtually all the workers lack PPE which signifies poor safety culture. Another factor can contribute to occurrence of accident is poverty level in the country, which made a 70 year old man (Figure 3) to be working as a labourer. Over 93% of the male workers (both labourers and bricklayers) worked at very high risk level while 76.9% of the female labourers worked at high risk level. The workers that were subjected to very high risk level required urgent investigation and implementation of changes to minimize or prevent chronic MSDs. Only 4.5, 25.6 and 14.4 % of male labourers, female labourers and bricklayers respectively are overweight. Though most workers (more than 70%) fell within the acceptable and medium range of CVL and CVS, yet, work intensity classification showed that average number (not less than 50%) of men (labourers and bricklayers) experienced moderate work intensity while most female (more than 63%) experienced heavy work intensity.

The following are therefore recommended to reduce accidents, MSDs and injuries and improve the health status and risk levels of the workers in order to increase productivity.

(a) PPE should be made available to the construction workers and their use should be motivated so as to minimize the effect of accident on them.
(b) Awkward working posture and repetitive activities should be reduced by having a work shift plan
(c) Comprehensive safety issues should be reported and documented for better planning and productivity.

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