Simulation study of typical auto-mechanics tasks

Oluranti Adetunji ABIOLA*, Adekola Olayinka OKE, Olufemi Adebola KOYA, Banji Zacheous ADEWOLE

Department of Mechanical Engineering, Obafemi Awolowo University, Ile-Ife, 22005, Nigeria
E-mail: abiolaolurantiadetunji@yahoo.com

* Corresponding author, phone: +2348051822714

Abstract

This study evaluates the heart rate of healthy non-mechanics handling predetermined loads, in postures typically used by roadside auto-mechanics during repair. The heart rate for different age groups and work postures of roadside auto-mechanics were determined from the assessment of healthy non-mechanics of the same age limit using a digital premium pressure monitor. Regressions were then developed to predict the heart rates of the auto-mechanics. The result indicated that load and posture adopted by roadside auto-mechanics, accounts for 2.74% and 4.51% of increase in their heart rate respectively, while age accounts for 65.78%. It further revealed that heart rate increases with age and load handled, and also showed that heart rate is highest in bending posture, followed by stooping. In conclusion the developed regression algorithms were sufficiently adequate in predicting the heart rate of roadside auto-mechanics and it also indicated that older roadside auto-mechanics need not engage in arduous tasks.

Keywords

Heart rate; Age; Posture; Load; Auto-mechanic

Introduction

As body posture changes with tasks, autonomic output regulates cardiac function (e.g., heart rate), to maintain a stable internal environment. At first glance, the heart appears to beat regularly; however, the interval between one heartbeat and the next is not the same [1]. Heart rate (measured in beats per minute (bpm)) is the number of times a person's heart beats in an amount of time; the maximum heart rate is the highest heart rate an individual can achieve without severe problems through exercise and it depends on age [2]. Heart rate increases with work [3, 4]. People's heart rates change depending on whether they are resting or exercising [5]. According to Babiker *et al*. [6] the heart rate of a healthy adult at rest is around 72 bpm. At rest, athletes normally have lower heart rates than other people while babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm [7]. The heart rate rises gradually during exercises and returns slowly to the rest value after exercise [6, 8]. The increase in heart rate depends largely on the intensity and duration of force or load applied during exercise or work, and the body's initial level of fitness [9].

Roadside auto-mechanics during engine repair adopt different and often awkward posture such as, standing, bending, leaning on auto-body, squatting, stooping, sitting on a seat, sitting on the ground, supine, side supine, which are considered as strenuous and familiar source of fatigue. The degree of the fatigue depends on the frequency and length of application of the muscle forces that must be applied, together with the nature of the work (static or dynamic) [10]. Fatigue and muscular pain is associated with manual lifting and it is more prevalent in older workers [11]. Physical exertion can be measured in a number of ways such as measuring heartbeats, electromyography or measuring oxygen consumption, and the limits for continuous work can be derived accordingly [12]. An alternative is to measure the amount of work done on external objects [10].

Body posture significantly influences heart rate in humans. Postural change, results in blood pressure change due to gravity [13]. In healthy adults, heart rate variability has been compared across different posture such as supine and right- and left-side lying postures, supine and right-side lying postures, supine and sitting postures, supine and standing postures, supine, standing, and head-up and -down tilt postures [1], standing, sitting and supine [14].

Meanwhile, genetic factors, fitness level, gender, age, weight lifted and adopted posture, atmospheric conditions such as temperature and humidity, physical and health conditions influence exhaustion and increases heart rate [15-17]. The amount of effort made during the work period can be measured by assessing the heart rate. Consequently, the study seeks to evaluate the effect of age, along with the load and common posture adopted by auto-mechanics on their heart rate, with a view to predicting the heat rate of people of different ages handling various degrees of load in different postures. The choice of auto-mechanics is based on the fact that they are the most predominant work-force along Lagos-Ibadan expressway, which has been described as the busiest road in Nigeria with over 270,000 vehicle plying it on a daily basis [18]. Their service is very pertinent to the smooth running of transportation along this route.

Material and method

Selection of subject

Fifteen (i.e. a total of seventy-five (75) out of about 311 people)healthy subjects(mechanics and non-mechanics) who have similar physical characteristics were probabilistically selected for each age group (below 25, 25-34, 35-44, 45-54 and above 54 years). The reason for these groups of age is because this is the range of age of apprenticeship and retirement in this trade. The purpose of the study was explained to the selected people (adults) in order to obtain their consent which they freely gave after the presentation of our identity card that we are researchers from the University. In Nigeria, studies for academic purposes do not require an approval of any agency or body as long as the consent of the people concerned was obtained. Non-mechanics served as subjects for the laboratory experiments.

Before starting the experiment, inherent risk was fully disclosed to the participants in order to obtain their consent to serve as human subjects during experimentation. Furthermore, participants were briefed with the protocols of the experiments used as well as the methods of investigation.

The 5, 15 and 25 Kg loads were also prepared by filling 5, 10 and 20 liters’ gallon respectively with appropriate quantity of sand.

Experimental design

The independent variables in the study include: load (5 Kg as light load; 15 Kg, medium load; and 25 Kg, heavy load), age group (below 25; 25-34; 35-44; 45-54 and above 54 years), and work posture (standing; stooping and supine). The study analysed the effect of these variables on heart rates. The experiment was carried out with three replicates of each age group for duration of 10 minutes for each experimental run.

Statistical significance of these parameters on the heart rate of subjects was examined using linear regression analysis and Duncan Post-hoc test (Statistical Analyses System, 9.1.3 Portable).

Measurement of heart rate of subjects

The heart rates of 3 non-mechanics, randomly selected for each age group classification were measured using a premium pressure monitor with comfit cuff (HEM-780, Omron Healthcare, USA) as shown in Figure 1.

(a) (b)

***Figure 1**. 25-34 years non-mechanic handling light load in (a) bending and (b) stooping posture*

Each subject was made to carry predetermined mass of loads (light, medium, and heavy) using the prescribed work postures bending, stooping or supine found to be common among roadside auto-mechanics in the study area. The cuff was applied to the left upper arm of the subjects and single experiment was carried out on each subject per day to ensure subjects were fit enough for the next experiment.

The pulse rate was determined for the different postures, while the subject was not handling any mass of load. This was collected as the control heart rate of the subject.

Subsequent heart rate was then determined as the subjects handled the various predetermined loads in the different postures.

The heart rates were determined and recorded at every 60 seconds for up to 10 minutes, and was replicated 3 times for each load.

Results

Variation of heart rate with posture and age of respondents

The results show that heart rates of non-mechanics of the different age groups are different (Figure 2).

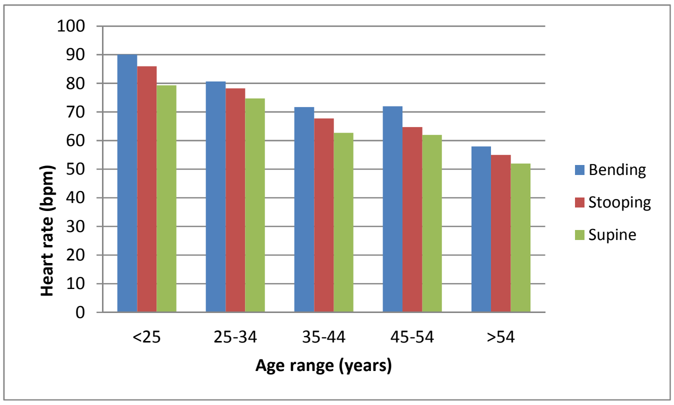

Figure 2. *Heart rate of subjects carrying no load at different postures of each age range (the excel file is provided in the appendix)*

Implication of load, posture and age on heart rate

The results (Figure 3, 4 and 5) show clearly that the mean heart rate of youthful people handling light (105 bpm for bending; 102 bpm for stooping; and 100 bpm for supine), medium (110 bpm for bending; 107 bpm for stooping; and 108 bpm for supine) or heavy load (118 bpm for bending; 112 bpm for stooping; and 108 bpm for supine) is higher compare to older ones. It was also found that subjects handling repetitive load in bending posture have higher heart rate compared to subjects performing the same task in stooping and supine posture.

Effect of load

The analysis show that, load significantly affect heart rate of mechanics at 99% confidence level ($p<0.0002$) and it accounts for 2.74% of the increase in heart rate (Table 1).

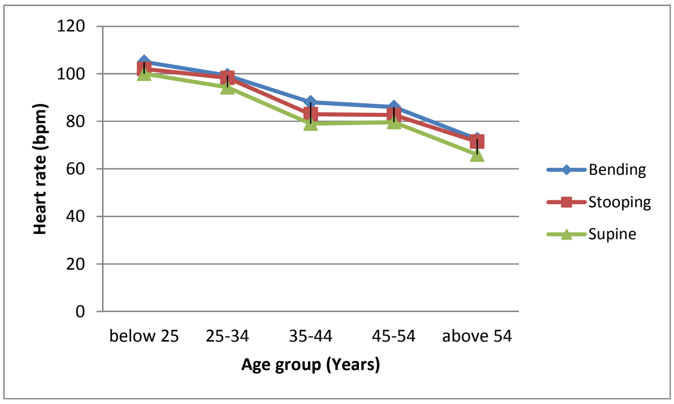

Figure 3. *Heart rate profile of healthy subjects; handling light load of 5 Kg in bending stooping and supine posture*

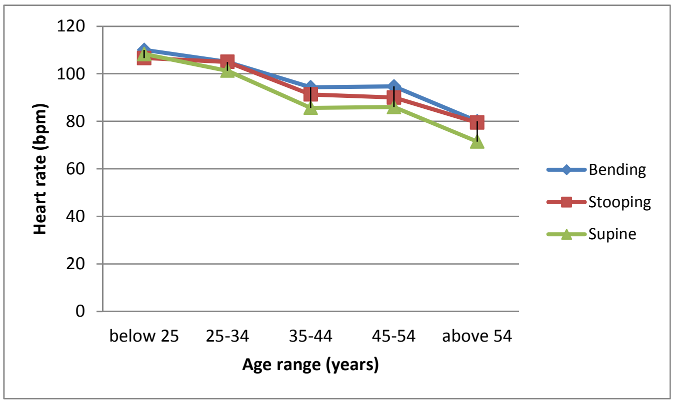

Figure 4*. Heart rate profile of healthy subjects; handling light load of15 Kg in bending stooping and supine posture*

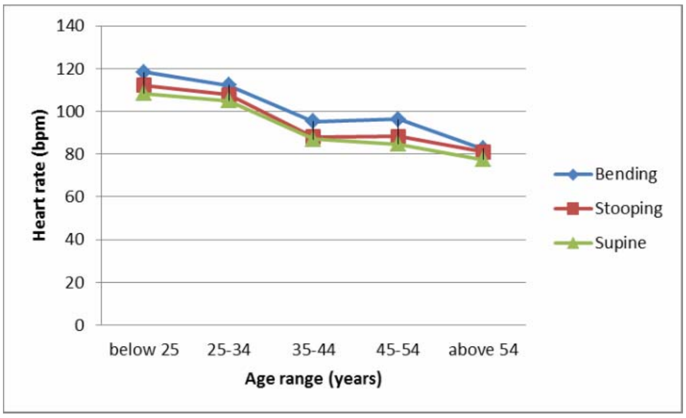

Figure 5. *Heart rate profile of healthy subjects; handling light load of 25 Kg in bending stooping and supine posture*

The regression model for heart rate based on load (Table 2) was found to be:

$$H = 78.90193L + 0.28648 \quad (1)$$

$R^2 = 0.0274$, $R^2_{adj} = 0.0254$, $F = 13.89$

where H is the heart rate (bpm) and L is the load in (Kg).

Table 1. Effect of individual factors on heart rate

Source	DF	Sum of Square	Mean Square	F-value	p-value	R^2
Effect of load on heart rate						
Model	1	2708.31316	2708.31316	13.89	0.0002	0.0274
Error	493	96135	194.99934			
Corrected Total	494	98843				
Effect of posture on heart rate						
Model	2	4455.61649	2227.80825	1.62	<0.0002	0.045078
Error	492	94387.37072	191.84425			
Corrected Total	494	98842.98721				
Effect of age group on heart rate						
Model	1	55131	55131	692.42	<0.0001	0.5931
Error	493	37820	79.62072			
Corrected Total	494	92951				

Effect of posture

It was found that, posture significantly affects heart rate of mechanics at 99% confidence level (p< 0.0001), and it accounted for about 4.51% of the increase in heart rate (Table 1). The parametric estimate of heart rate based on posture (Table 2) and the regression model equation from the different work posture was found to be:

$$H= 79.58181818B + 7.34642424 \quad (2)$$

$$H= 79.58181818St + 7.50545455 \quad (3)$$

$$H= 79.58181818B + 0.00000000 \quad (4)$$

where, *H* is the heart rate (bpm); *B* is the bending posture; *St* is the stooping posture and *Su* is the supine posture with an approximate value of 1.00. (R^2= 0.04578, R^2_{adj} = 0.0254 and F = 11.61)

The predictive model in Equation (2), (3) and (4) for the exhaustion heart rate for the different postures may be useful to predict the heart rate of auto-mechanics in bending, stooping and supine posture respectively, without the effect of time, load or age group.

Effect of age group

Following a one-way classification analyses of variables, it was found that, age significantly affect heart rate of mechanics at 99% confidence level (p $\leq$ 0.0001), and accounted for about 65.78% of the increase in heart rate (Table 1). The parametric estimate of heart rate based on the age group is shown in Table 2 and the regression model equation from the different age group was found to be:

$$H = -0.784A + 113.159 \quad (5)$$

where, H is the heart rate of non-mechanics aged below 25 years (bpm) and A is approximately 1.00

The predictive model in Equation (5) for the exhaustion heart rate for age groups may be useful to predict the heart rate of auto-mechanic in any age group.

Table 2. Parameter estimate of effect of individual factors on heart rate

Variable	Estimate	Standard Error	T-value	p-value
Parameter estimate of load on heart rate				
Interception	78.90193	1.31281	60.10	<0.0001
Load (Kg)	0.28648	0.07687	3.73	0.0002
Parameter estimate of posture on heart rate				
Interception	79.58181818	1.07828216	73.80	<0.0001
Bending	7.34642424	1.52492126	4.82	<0.0001
Stooping	3.50545455	1.52492126	2.30	0.0219
Supine	0.00000000	-	-	-
Parameter estimate of age group on heart rate				
Interception	113.1585	1.23218	91.84	<0.0001
Age group (yrs)	-0.74749	0.02841	-26.31	<0.0001

Effect of the different classifications of each variable

It was found that the effect of 15kg, medium load (84.6 bpm) on heart rate is not significantly different from that of 25kg, heavy load (85.4 bpm) (Table 3). Meanwhile, the effect of 5kg light load (79.6 bpm) on heart rate was found to be significantly different from the two other loads.

Table 3 shows that the mean heart rate of bending, stooping and supine posture is significantly different. The mean heart rate of bending posture (86.9 bpm) is significantly higher than the mean heart rate of stooping (83.1bpm) and supine posture (79.6 bpm).

It was found that, the mean heart rates is significantly higher for the ages 25 years and lower for the age of 54 years (Table 3), except for the age groups 35-44 and 45-54 years.

Discussion

Variation of heart rate with posture and age of respondents

The findings here are in agreement with reports of previous researchers [1, 14] where it was reported that, body posture significantly influence heart rate in humans.

Table 3. Comparison of the effect of different classes of mass of load,posture and age on heart rate

Duncan Group	Mean Heart rate (bpm)	N	Variable
Mass of Load			
A	85.3579	165	25 (heavy)
A	84.6112	165	15 (medium)
B	79.6283	165	5 (light)
Postures			
A	86.9282	165	Bending
B	83.0873	165	Stooping
C	79.5818	165	Supine
Age Groups			
A	99.275	99	<25 years
B	92.336	99	25-34 years
C	79.244	99	35-44 years
C	78.620	99	45-54 years
D	66.520	99	>54 years

Means with the same letter are not significantly different
A ($P < 0.0001$) B ($P < 0.0001$)

The heart rate decreases with age and varied with work postures. Heart rate was found to be highest in bending posture, followed by stooping and then supine postures. In supine position, the internal jugular veins of humans are the primary venous drain for the brain. In sitting and standing however, the positioning of these veins above the heart level causes them to collapse due to gravity, resulting in increased blood pressure [19, 20].

The higher heart rate observed with bending posture and the lower heart rate with supine may be due to fast heart rate associated with upright posture, such as, standing and sitting compared with lying posture [14]. It is important to note that higher heart rate associated with upright posture may be attributed to higher acceleration due to gravity experienced by subjects in bending posture, as they have to do more work in order to withstand gravity. Although, higher heart rate experienced in bending may rapidly result into exhaustion, when compared with stooping and supine; auto-mechanics in stooping and supine posture cannot handle much load in these postures as may be possible in bending posture. The limitation is primarily due to the restriction associated with stooping and supine postures.

The decreasing trend in heart rate with age found in this study is also in agreement with Choi *et al*. [21] &Carter *et al*. [22]. This may be due to dramatic drop in physical strength or body function deterioration with increasing age as claimed by Yukishita *et al*. [23].

Implication of load, posture and age heart rate

It was notice that time taking to sustain work in stooping posture is reduced compared to the other postures, though subjects have reduced heart rate when compared to subjects in bending posture; which is an indication that working in stooping posture can be an arduous task. This may be due to muscular imbalance and high strain on the low-back muscle associated with stooping posture [24].

Age accounted for approximately 65.8% of heart rate on the job. This explains why aged people are not many in the trade; as work load must be reduced for aged people in the trade to ensure safety, comfort, effectiveness and productivity [23, 25].

The remaining 26.5% of the increase in heart rate that was not accounted for may therefore be attributed to other work stressors such as ultra-violent and thermal radiation, hot and noisy environments, dust, fumes, oils, grease and other chemicals, improvised or improperly designed tools and machinery and work in deplorable workplace as described by Vyas*et al.* [26].

Conclusions

The study shows that the ages of people have higher effect (65.8%) on heart rate when compared with posture (4.5%) and work or load sustained (2.7%).

It also shows that higher heart rate is experienced in bending, followed by stooping and supine, either load is sustained or not, and that the developed models were sufficiently adequate in defining heart rate of mechanics and non-mechanics in common posture adopted by auto-mechanics during repair work.

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