



Research Article

## Safe work-impulse chart for roadside auto-mechanics

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The work evaluates the response of the heart rate of non-mechanics handling some specific loads in the common postures employed during road-side repair of automobile and later, the result was validated with the auto-mechanics during repair activities. The purpose is to specify the safe work-impulse of auto-mechanics in the common postures, such as, bending, stooping and supine posture, used during roadside repair. The safe work-impulse was determined for preselected healthy non-mechanics of the classified age groups who gave informed consent. Increase in heart rates at exhaustion of non-mechanics in each age group, in lifting predetermined loads were measured using digital premium pressure monitor with a comfit cuff. Consequently, the work-impulse charts for the load classifications and different age-groups were developed for the different postures. The heart rates of the auto-mechanics performing specific tasks during engine repairs were then measured to determine the equivalent work-impulse, using the developed charts. The result revealed that, auto-mechanics handling the same mass of load under the same conditions have lower safe work-impulse. In conclusion, the study reveals that roadside auto-mechanics have the capacity to sustain higher safe work-impulse in bending and supine postures than in stooping posture.

**Key words:** Heart rate, auto-mechanic, repair, posture, automobile, work-impulse.

### INTRODUCTION

Repair operation of automobile engine is predominantly characterized by male workforce, who must interact effectively with their environment, to ensure optimum performance, not only of self, but also of the repaired engine and equipment. Equipment serves as extensions to parts of the mechanics body. It is designed to make repair works such as bending, twisting, lifting, reaching, hammering, cutting, screwing, spray painting, cleaning, welding and handling of tools easy and efficient, with less physical exertion (Vyas *et al.*, 2011). The use of improper tools has been identified as a cause of fatigue, pains in the muscles and injuries to workers (Environmental Health Safety, 2006), particularly when used repetitively or for a prolonged period. Human fatigue is now recognised around the world as being the main cause of accidents in the industries (Beaulieu, 2005).

Fatigue is described as the temporary inability, or decrease in ability, or strong disinclination to respond to a situation, because of previous over-activity. It is characterized by reduction in performance after

continuous workload accompanied by subjective experience of exhaustion (Hill, 2003; Darby *et al.*, 1998; Wantanabe *et al.*, 2007) and can either be mental, emotional or physical.

Although, fatigue can compromise health and safety at work, and is a common outcome of stress. It is almost impossible to measure except in specialised situations.

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**Plate 1:** 25-34 years non-mechanic handling light load in (a) bending and (b) stooping

However, physical exertion as a familiar source of fatigue is a function of force applied (Moreira *et al.*, 2014), common among mechanics during repair. Its degree depends on the frequency and length of application of the muscle forces that must be applied, together with the nature of the activity. Fatigue (physical exertion) can be measured in a number of ways, such as, counting hearts, electromyography or measuring oxygen consumption; and the limits for continuous work can be derived accordingly (Tsurumi *et al.*, 2002). An alternative is to measure the amount of work done on external objects, such as the total weight lifted during the day.

Meanwhile, auto-mechanics become visibly tired or exhausted during physical activity (Joseph *et al.*, 2011) caused by inadequate tool and poor working environment. The use of improvised tools necessitates the need for auto-mechanics to adopt awkward postures during repair. Awkward postures adopted by auto-mechanics result into pain, back strain, muscular tiredness and fatigue, musculoskeletal disorder and work stressors (Andrew, 2006). However, work posture and the physiological load of the auto-mechanic are important physiological stress determinants that must be monitored and controlled for the most effective and efficient and optimal system output. Physiological load can be monitored by applying the principle of heart rate counting to prevent exhaustion among roadside auto-mechanics. Heart rate is the number of times a person's heart beats in an amount of time. Heart rate increases with work (Jensen *et al.*, 2013; Jouven *et al.*, 2009). People's heart rates change if they have been resting or exercising (Rowland, 2011). According to Babiker *et al.* (2011) the heart rate of a healthy adult at rest is around 72 bpm. Athletes normally have lower heart rates than less active people. Babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm. The heart rate rises gradually during exercises and repetitive work and returns slowly to the rest value after exercise (Kothari, 2014; Babiker *et al.*, 2011).

Consequently, this study was conceived to assess the heart rate of the auto-mechanic population in the common postures (bending, stooping and supine) employed during roadside repair of automobile. Availability of the heart rate measurement, will facilitate the development of a safe work-impulse chart for the mechanics; and provide information require for adequate use of muscular force, prevention of fatigue or physical exertion, during repair. Therefore, the main objective of this paper was to present the heart rate measurements of the non-mechanic in the common postures employed during road-side repair of automobile, with the view to developing safe work-impulse chart, aimed at specifying work limit for the auto-mechanics.

## MATERIALS AND METHODOLOGY

### Selection of Subject for Laboratory Experiments

Fifteen healthy non-mechanics, who have similar physical characteristics with the mechanics, were selected for each age group classification of the auto-mechanics (below 25, 25-34, 35-44, 45-54 and above 54 years). The non-mechanics served as subjects for the laboratory experiments.

Before starting the experiment, inherent risk were 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.

### 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 Plate 1.

Each subject was made to carry predetermined mass of loads (light load, 5 Kg; medium, 15 Kg, and heavy, 25 Kg) using the prescribed work postures (a; bending, b; stooping or supine) found to be common among roadside auto-mechanics in the study area. A single experiment was carried out on each subject per day to ensure subjects were fit enough for the next experiment.

The cuff was applied to the left upper arm of the subjects, as shown in Plate 1. The number of pulse count was determined for the different postures, while the subject was not handling any load. This was noted 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.

### Heart rate of Mechanics at Work

The heart rate measurement was carried out directly on roadside auto-mechanics carrying out repair work on an automobile engine. The number of pulse count was determined from the pressure monitor before start of repair work and then recorded as control heart rate. Subsequent heart rate was then determined as auto-mechanics commenced repair work. The heart rate was determined and recorded at every 60 seconds until auto-mechanics completed the task.

### Estimation of Work-Impulse

The safe work-impulse for the different age groups was determined for the different work postures of the mechanics. In each age group, increase in heart rate was plotted against work-impulse up to 10 minutes. The time at which the maximum heart rate occurred, was identified as the safe work limit and was used to calculate safe work-impulse as shown in Equation (1).

$$I = L * g * t \quad (1)$$

where,  $I$  is the work-impulse in Newton-Seconds (Ns) ( $\text{Kgms}^{-1}$ );  $L$  is the mass of load in Kilograms (Kg);  $t$  is the time of maximum heart rate occurrence in Seconds (S), and  $g$  is acceleration due to gravity taken as  $10 \text{ mS}^{-2}$ .

The work is indicated by the amount of load repetitively handled by the workman. While work-impulse was considered as the force applied by mechanics over time, safe work-impulse was taken as the work limit at exhaustion of each healthy non-mechanics. It was referred to as the work-impulse at which heart rate of auto-mechanics reached its maximum, due to fatigue or tiredness. Consequently, the safe work-impulse of average men handling the different categories of load

using three different postures was drawn. The heart rates of auto-mechanics during engine repair work were also measured, to determine the equivalent work-impulse using the developed chart.

## RESULTS

### Effectiveness in Handling Light Load

The effectiveness in handling light load (Figure 1) shows that, non-mechanics handling light load of about 5 Kg experienced a gradual increase in heart rate, for up to 600 seconds of the experiment, without reaching their limit or exhaustion point. This indicates that, it takes a longer time than 600 seconds, before non-mechanics handling light load are exhausted.

### Effectiveness in Handling Medium Load

The effectiveness of non-mechanics handling medium load (Figure 2) shows that, the safe work-impulse decreases with the subjects of older ages, for all the three postures. The analyses of the result, shows that there is no significant difference i.e. the probability value (p-value) is less than 0.05 ( $p < 0.05$ ) in the safe work-impulse of the subjects in bending or supine postures for all the age group; the limits for both postures are significantly higher ( $p < 0.05$ ) than the safe work-impulse in the stooping posture.

### Effectiveness in Handling Heavy Load

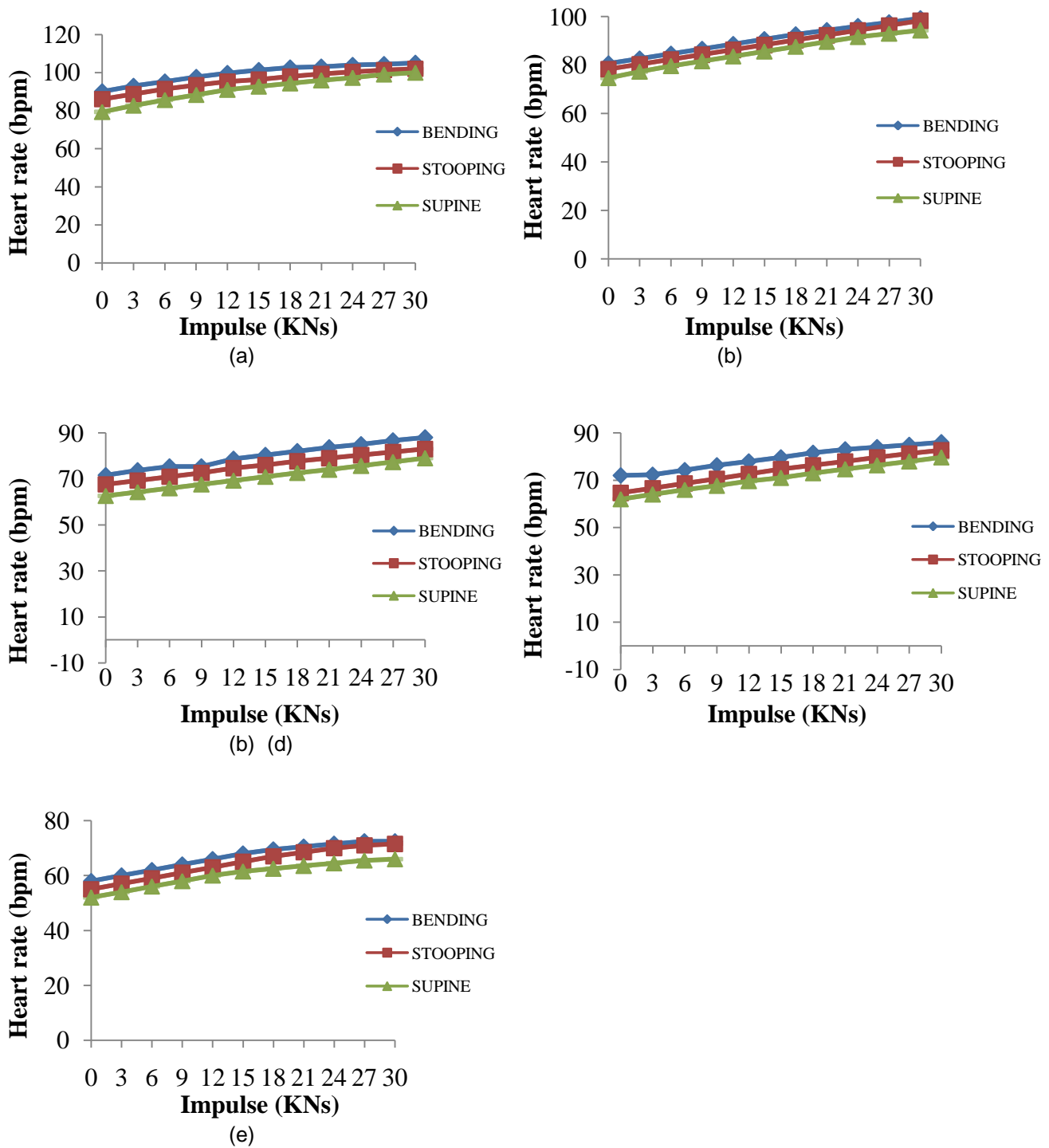
The effectiveness of non-mechanics handling heavy load of about 25 kg shows that they were exhausted much quickly, between work-impulse of 60 KNs for men above aged 54 years in the 3 posture and 105.0 KNs for men between ages 25-34 years in bending and supine posture (Figure 3). It was found that those above 54 years, for all postures, gets exhausted at the smallest work-impulse; followed by those between ages 35-44 years in bending posture and 45-54 years in stooping posture.

### Estimated Safe Work-Impulse of Non-Mechanics in the Experiment

Analyses of safe work-impulse (Table 1) show more significant correlation (0.86 and 0.92) between the safe work-impulse of non-mechanics handling medium and heavy load respectively.

### Actual Safe Work-Impulse of Mechanics during Engine Repair Work

The work-impulse measurement observed while auto-mechanics carry out repair work (Figure 4) show that, heart rate of auto-mechanics fluctuates during work-



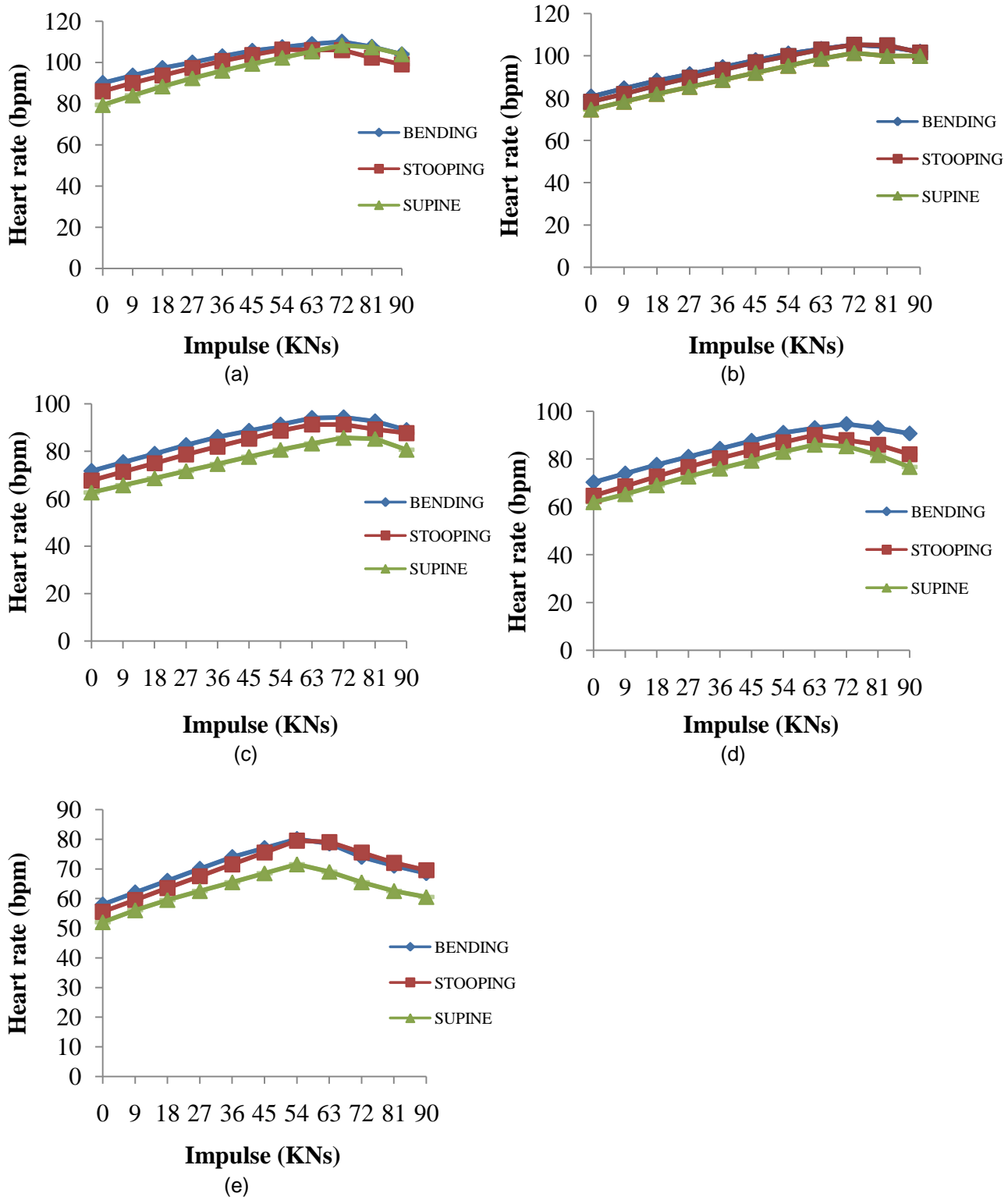
**Figure 1.** Safe work-impulse chart of non-mechanics handling light loads, 5 Kg in different postures: (a) below 25 years; (b) 25-34 years; (c) 35-44 years; (d) 45-54 years (e) above 54 years

period, irrespective of the posture. It was found that the auto-mechanics aged between 25 and 34 years in mostly bending posture were exhausted within 480 seconds and heart rate of 99 bpm. In mostly stooping posture the subjects were exhausted within 420 seconds and heart rate of 101 bpm. Those between ages 35-44 years in stooping posture were exhausted in 420 seconds with heart rate of 75 bpm.

**A Comparison of Experimental and Actual Safe Work-Impulse**

A comparison of the results of experimental and actual safe work-impulse obtained from non-mechanics and auto-mechanics respectively show that:

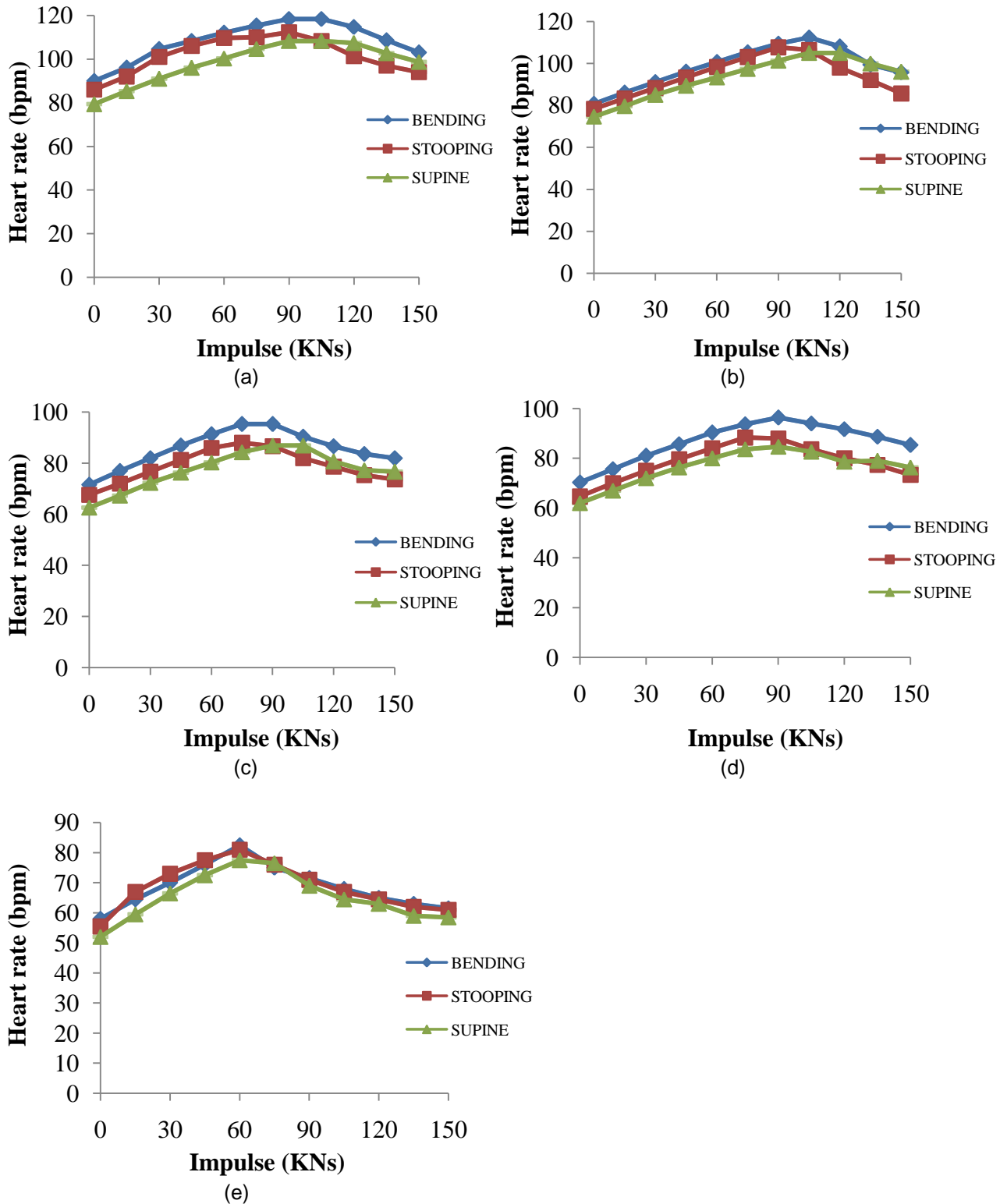
- (i) The heart rate of auto-mechanics between ages 25-34 years in mostly bending posture show a more



**Figure 2.** Safe work-impulse chart of non-mechanics handling medium loads, 15 Kg in different postures: (a) below 25 years; (b) 25-34 years; (c) 35-44 years; (d) 45-54 years (e) above 54 years

(ii) significant correlation (correlation coefficients are designated by  $R^2$  value) ( $R^2 = 0.96$ ) with non-mechanics of the same age group, handling medium load in bending

posture. Both were exhausted at the same time (480 seconds). The analyses of the result, shows that auto-mechanic between ages 25-34 years during engine repair



**Figure 3.** Safe work-impulse chart of non-mechanics handling heavy loads, 25 Kg in different postures: (a) below 25 years; (b) 25-34 years; (c) 35-44 years; (d) 45-54 years (e) above 54 years.

(iii) have similar work-impulse (72 KNs) as non-mechanics handling medium load in the same posture, but lower heart rate.

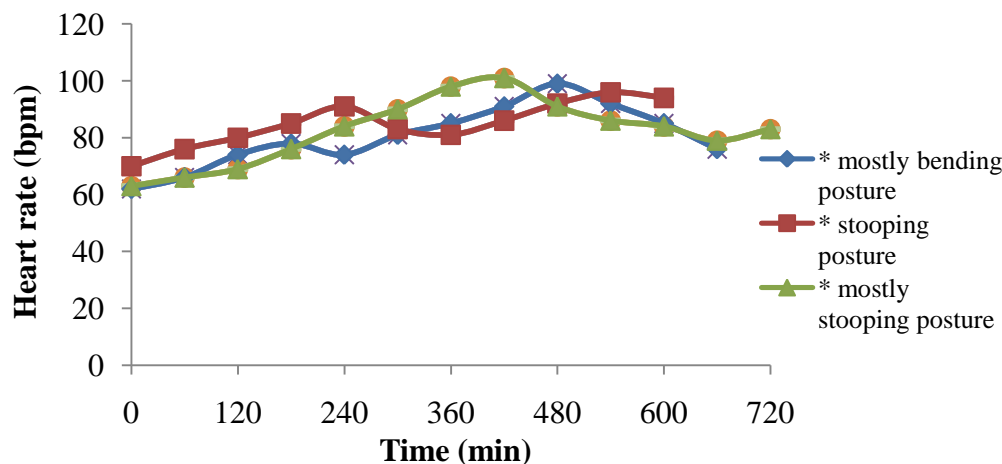
(iv) The heart rate of auto-mechanics between ages 25-34 years in stooping posture show a significant correlation with non-mechanics of the same age group,

**Table 1.** Summary of safe work-impulse for non-mechanics with different age, posture and load

Posture and Age	Repetitive load carried					
	Light (5 kg)		Medium (15 kg)		Heavy (25 kg)	
	Impulse (KNs)	Heart rate (bpm)	Impulse (KNs)	Heart rate (bpm)	Impulse (KNs)	Heart rate (bpm)
<b>Bending Posture</b>						
<25	-	105 (360)*	72	110.0 (480)*	90	118.3 (360)*
25-34	-	98.3 (360)	72	105.0 (480)	105	112.3 (420)
35-44	-	88.0 (360)	72	94.3 (480)	75	95.3 (300)
45-54	-	86.0 (360)	72	94.7 (480)	90	96.3 (360)
>54	-	72.5 (360)	54	80.0 (360)	60	82.5 (240)
<b>Stooping Posture</b>						
<25	-	102.0 (360)	54	106.6 (360)	90	112.3 (360)
25-34	-	98.3 (360)	72	105.0 (480)	90	107.7 (360)
35-44	-	83.0 (360)	63	91.3 (420)	75	88.0 (360)
45-54	-	82.7 (360)	63	90.0 (420)	75	88.3 (300)
>54	-	71.5 (360)	54	79.5 (360)	60	81.0 (240)
<b>Supine Posture</b>						
<25	-	100.0 (360)	72	108.3 (480)	90	108.3 (360)
25-34	-	94.0 (360)	72	101.3 (480)	105	105.0 (420)
35-44	-	79.0 (360)	72	85.7 (480)	90	87.0 (360)
45-54	-	79.7 (360)	63	86.0 (420)	90	84.7 (360)
>54	-	66.0 (360)	54	71.5 (360)	60	77.5 (240)

\* Numbers in parentheses are the time in seconds at exhaustion

- Subjects were not exhausted within the limit of experiment



**Figure 4.** Average safe work-impulse chart of 3 auto-mechanic in bending, stooping and supine posture during automobile engine repair

handling medium load in stooping posture. The analyses of the result therefore shows, that auto-mechanic between ages 25-34 years during engine repair have similar work-impulse (72 KNs) as non-mechanics handling medium load in the same posture, but lower heart rate.

(v) The heart rate of auto-mechanics between ages 35-44 years in mostly stooping posture show a higher correlation ( $R^2 = 0.94$ ) with non-mechanics of the same age group, handling medium load in stooping posture. The time of exhaustion is between that of non-mechanics handling medium and heavy load in stooping posture.

Therefore, safe work-impulse of auto-mechanics 35-44 years in mostly stooping posture during engine repair can be assumed to be similar to work-impulse (63 KNs) of non-mechanics handling medium load in stooping posture.

## DISCUSSION

The results shown in Figures 1 to 4 is an indication that it takes a longer time than 600 seconds before non-mechanics handling light load is exhausted. They also

show that accomplishing activities in the stooping posture are more arduous compare to bending and supine posture.

Generally, older men got exhausted much quickly at the smallest work-impulse when compare with younger ones (Table 1) while handling load in the same postures. However, it was obvious that non-mechanics between ages 25-34 have the highest work-impulse. This may be due to low muscular strength in older people. This is in agreement with Yukishita *et al.* (2010) which established the fact that human strength deteriorates with increasing age. Leyk *et al.* (2007) also established the fact that gradual loss of strength becomes functionally significant beyond 55 years of age for most men. Meanwhile, the lower heart rate and corresponding safe work-impulse experience by older non-mechanics in the study is also in agreement with Carter *et al.* (2003) i.e., during exercise, older individual has a lower heart rate. The higher heart rate observed with bending posture and the lower heart rate with supine may be due to fast heart rate associated with up-right posture, such as, standing and sitting compare to lying posture (Jones *et al.*, 2003).

The fluctuation in heart rate may be due to the variation in force applied by auto-mechanics as force demand varies from task to task. Force required for screwing and unscrewing is different from that required for removing piston from engine block or lifting heavy engine. The posture of the mechanic varied as the task demanded; although, a particular posture predominated as repair tasks progresses.

It was obvious that auto-mechanics generally experienced lower heart rate when compare to non-mechanics, even when they both apply the same force per time under the same condition. This may be due to the fitness of auto-mechanic as a result of continuous exercise and regular use of muscular forces by auto-mechanics. This is in agreement with Carter *et al.* (2003) which proposed that long-term endurance training significantly influences lower heart rate. Meanwhile, auto-mechanic's daily activities are nothing short of physical exercise, and regular practice of physical exercise is an important factor to reduce heart rate (Almeida and Araujo, 2003).

Repetitive physical exercise caused by the demand of engine repair leads to auto-mechanics working near exhaustion and this may results in skeletal fatigue and damage as well as reduced performance (Dawson *et al.*, 2003). Increased occupational health hazard associated with roadside automobile repair (Vyas *et al.*, 2011) may be as a result of auto-mechanics working near or up to exhaustion limit. Auto-mechanics working near exhaustion limits increase the likelihood of poor decision making, greater error and generally impaired performance.

## CONCLUSION

Health risks of the auto-mechanics will be minimized if they operate within the domains of their safe stress levels: 72 KNS for those below 25 years, handling medium repetitive load and including those up to 54 years; 105 KNS for those between ages 25-34 years, handling heavy repetitive load. Alternatively, mechanics below 25 years of age and up to 54 years of age should avoid continuous repetitive work beyond 480 seconds, and for those above 54 years of age they should avoid continuous repetitive work beyond 360 seconds. The safe work-impulse of auto-mechanics within the specified age bracket of 25-34 and 35-44 years of age, who are consistently involved in engine repairs can be more productively engaged for a prolonged period than the other categories (below 25, 45-54 and above 54 years of age). Thus, youthful mechanics between the ages 25-34 years are less susceptible to exhaustion when compared with mechanics of the other age groups. Also, roadside auto-mechanics have the capacity to sustain higher safe work-impulse in bending and supine postures than in stooping posture.

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