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Operations of Knapsack Sprayer and Its Impacts on Physiological Parameters of Selected Operators

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Abstract

The study was aimed at determining the impacts of operating Manually Operated Hand Lever Knapsack Sprayers (MOHLKS) on physiological responses of the operators as dependent on anthropometric variations and sex. Twenty eight subjects, (4 female, 24 male) Mean ± SD: Age 22.5 ± 1.92, 24.29 ± 2.2 years; Body Mass Index 24.6 ± 4.8, 21.7 ± 2.4 kg/m^2 were employed in the study. Selected anthropometric parameters of weight and height were used to determine body mass index (BMI), with these are arm-reach forward, elbow to fingertip, hand length and hand width were measured to establish human variations in diversity. Subjects undertook the operation at 5 replicates each, before and after which information about operators' body pain locations and body physiological changes of heart rates were obtained. Measured parameters were used in the determination of expended energy (EE), physiological cost (PC), oxygen intake (VO_2) and aerobic power (VO_2max). Alongside with these were operational parameters of stroke, pace and time taken to get the operation done and environmental factors of temperature and relative humidity. The results revealed on the average that the BMI (24.61 ± 4.78 kg/m^2) in female operators was higher, this corresponded to PC and VO_2, while the VO_2max (34.83 ± 3.30 ml/min/kg) in males is higher. More EE was obtained in female subjects (3.53 ± 3.76 kCal/min) as compared to male subjects (3.42 ± 7.48 kCal/min). The main effects plot of operational factors on EE displayed the stroke made by the subjects during spraying operation as parameter with largest effect on EE. Regression equation for EE and PCI is given as PCI = 1.97 + 25.2 EE, while the P-value at α = 0.05 is 0.000 and R^2 = 98.8%. Post operational body pain showed that 19 out of 28 subjects incurred at least one type of body pain, with shoulder pain as most frequent. The results of the study suggest that early incidence of fatigue may occur in female operators as compared to the males, and in addition, cumulative trauma at shoulder, back, and upper and lower arm may result over time. Hence, it is recommended that the tank volume should be reduced and the straps for the shoulders should be supported with additional cushion.

Keywords

Cumulativetrauma, Knapsack Sprayer, Operational Effect, Physiological Changes, Stroke

1. Introduction

The relevance and the utilization of knapsack sprayers corroborated with the increasing demand of same resulted from growing concern in the application of pesticides (insecticides, fungicides and herbicides) on the farm to aid optimum yield of agricultural products and also, for fumigations in residential areas for health reason can in no way be over emphasise in the black nations of the world in which Nigeria is not exempted. [1] Lambrecht *et al.* (2019) reported that manually operated knapsack sprayers are utilised to introduce various products like pesticides and bio-fertilizers that are enlisted in the phytosanitary control phase in diverse arable crops. Spray discharges are made by initiating and releasing liquid particles in order to control pests, increase productivity in farms, and collaborate with the world agricultural production.

[2] Rabbani *et al.* (2020) said that the application of pesticides is mostly done using lever operated knapsack sprayers. Knapsack sprayers are employed on a large scale by small, medium, and large farmers as a result of their sizeable adaptability. This equipment has features that meet the existing needs in rural settings, as they have a low purchasing cost and permit products to be applied in individual societies [1]. A hand operated sprayer is a continuous type of sprayer with a fairly constant discharge rate. A person maintains pressure in the tank by pumping air with a lever with one hand and directs the spray lance with the other hand. The recommended lever strokes per minute are 20 - 30 and 10 - 25 [3]. Maintaining a constant pressure is very difficult with a manual knapsack sprayer and causes user fatigue due to maintaining a constant pressure and excessively heavy bulky construction [3].

The most prevalent type of knapsack sprayer in Nigeria is the mechanical type that requires operators to continually move the pressurizing device by their hands in order to pressurize the liquid contained in the heavy knapsack tank and get it to spray through the nozzle [4]. [5] Freitas (2006) submitted that repetitive effort can result to muscular fatigue, a fact that has not been researched for knapsack sprayers. As presented by [2] workers, when using heavy equipment are subject to fatigue and development of musculoskeletal problems. In line with this, it was recommended that the adoption of posture training, workout gymnastics and the adoption of scheduled breaks to mitigate the risks involved due to the sprayer weight. This recommendation is hardly followed by the users of knapsack sprayers.

Though in the country, no significant ergonomics evaluations has been carried out on Manually Operated Hand Lever Knapsack Sprayers (MOHLKS), but as a results of after usage complaints by operators, some efforts are being directed towards the development of more "portable and convenience in use" which in the actual facts are not yet in circulation. Earlier efforts at developing sprayers were made by many researchers such as [6]. These sprayers were reported on varying performances; however the evaluations results were mainly related to the machines and not the users.

The identified knapsacks sprayers that are widely used in the country are characterized with no age range as well as the sex of the end users. Hence, the aim of the study is to determine the impacts of MOHLKS on the end users, in relationship with their anthropometry variations and physiological responses as the patronage of the equipment is gaining more relevancies by the day.

2. Materials and Method

2.1. Description of the Equipment Used in the Experiments

- Capacity for 16.0 liter tank made of polyethylene to hold liquid content;
- Hand lever (handle diameter of 2.4 cm) to pump and create pressure within the tank;
- Mounting straps;
- Filtration system behind the nozzle tip to reduce blockages;
- Control Valve to control pressure and turn of the sprayer;
- Nozzle tip to control application rate and produce the correct size droplets (**Figure 1**).

2.2. Experimental Procedure

The experiment was carried out on the open field of 100 m^2 at the Southern Farm of the Federal College of Agriculture, Ibadan. Only water was used as liquid

Figure 1. Typical picture of manually operated hand lever knapsack sprayers.

to fill the sprayer into the full capacity of 16 liters having the total weight of 22 kg. The maximum height of the vegetation on the field was determined 15.3 cm. Twenty eight subjects (4 female, 24 male) of minimum and maximum ages of 20 and 28 years respectively were employed in the operation with five replications per each subject. Before the experiment, the anthropometric measurements (weight, height, arm-reach forward, elbow to fingertip, hand length and hand width) of all the subjects were determined. The physiological parameter of heart rates of the subjects was measured at rest and after the completion of each spraying operation on the experimental field together with environmental factors of temperature and relative humidity. Time taken to complete each replicate by the subjects were recorded, alongside with this are numbers of paces and strokes made by individual subject in each completion. After spraying, the subjects were orally interviewed on the effect of the operation on their physical body parts, and their responses were noted and recorded. Some measured parameters were used in the determination of body mass index (BMI), expended energy (EE), physiological cost index (PCI), and oxygen consumption rate (VO_2) and aerobic power (VO_2max).

2.3. Determination of Some Models

Body mass index (BMI):

$$\mathrm{BMI} = \mathrm{weight}/\mathrm{height}^2 \left(\mathrm{kg}/\mathrm{m}^2\right) \tag{1}$$

Energy expenditure (EE)

$$\mathrm{EE} = 0.039 * \mathrm{HR} - 2.33 (\mathrm{kcal}/\mathrm{min}) \tag{2}$$

where, EE = Energy expenditure and

HR = Measured heart rate after a task is performed

Maximum heart rate (HR_{max}):

$$\mathrm{HR}_{\max} = 205.8 - 0.685 * \mathrm{age} (\mathrm{bpm}) \tag{3}$$

Oxygen consumption rate (VO_2):

$$Y = 0.259X - 6.422 (\mathrm{L}/\mathrm{min}) \tag{4}$$

where: Y = predicted oxygen consumption;

X = measured heart rate

Physiological Cost Index:

$$\mathrm{PCL} = \mathrm{HR}_{\mathrm{w}} - \left(\mathrm{HR}_{\mathrm{r}}/\mathrm{V}\right)(\mathrm{P}/\mathrm{min}) \tag{5}$$

Aerobic power (VO_2max)

$$\mathrm{VO}_2 \max = \mathrm{HR}_{\mathrm{w}} - \left(\mathrm{HR}_{\mathrm{r}}/\mathrm{V}\right)(\mathrm{P}/\mathrm{min}) \tag{6}$$

2.4. Statistical Analyses

Descriptive statistics were calculated for all variables. Chats, matrix plot were used and main effect plot in analysis of variance (ANOVA) was utilized to determine the differences in the effects of each variable with the other and to see relationships among pairs of variables. All statistical analyses were conducted using MINITAB 14.exe and Microsoft excel 2014.

3. Results and Discussion

Table 1 presented descriptive statistics of anthropometry, physiological and operational parameters, expression of subjects before and after performing spraying operation is presented in Table 2. Figures 1-4 showed plots on interrelationships among the physiological parameters, the effects of anthropometric factors on

Table 1. Descriptive statistics of anthropometry, physiological and operational parameters.

Variable	sex	Mean	SE	Mean	StDevCoefVar	Minimum	Maximum	Skewness
Age (yr)	M	24.29	0.45	2.22	9.12	20.00	28.00	0.93
	F	23.50	0.96	1.92	8.15	21.00	25.00	1.77
BMI (kg/m^2)	M	21.69	0.48	2.35	10.82	18.33	27.76	−0.22
	F	24.61	2.39	4.78	19.40	21.55	31.63	1.77
armreach-forward	M	85.64	0.85	4.15	4.84	78.00	93.11	−0.22
	F	78.00	2.60	5.19	6.65	72.00	84.10	0.05
Elbow-finger (cm)	M	50.45	0.58	2.81	5.57	45.00	55.00	−0.05
	F	45.83	1.00	2.00	4.37	43.00	47.70	−1.30
hand length (cm)	M	19.97	0.24	1.16	5.80	18.20	22.50	0.62
	F	18.13	0.39	0.78	4.35	17.00	18.80	−1.44
hand width (cm)	M	10.78	0.16	0.80	7.38	9.00	12.70	0.34
	F	10.03	0.30	0.60	5.89	9.20	10.50	−1.30
stroke	M	46.04	6.57	32.16	69.85	7.00	128.00	1.35
	F	34.00	0.40	20.80	61.32	12.00	62.00	0.82
time taken (min)	M	2.36	0.21	1.01	43.04	1.03	5.42	1.34
	F	2.85	0.71	1.41	49.70	2.00	4.95	1.91
pace	M	124.90	12.70	62.30	49.88	56.00	270.00	1.11
	F	111.30	40.80	81.50	73.27	56.00	230.00	1.69
HRrest (bpm)	M	82.13	1.51	7.41	9.02	69.00	93.00	−0.33
	F	85.25	2.63	5.25	6.16	78.00	90.00	−1.16
HRwork (bpm)	M	89.96	1.34	6.55	7.28	77.00	102.00	0.19
	F	92.75	1.70	3.40	3.67	88.00	96.00	−1.20
EE (kcal/min)	M	3.42	0.05	0.26	7.48	2.91	3.89	0.19
	F	3.53	0.07	0.13	3.76	3.34	3.65	−1.20
HRmax (bpm)	M	189.16	0.31	1.52	0.80	192.10	192.10	−0.12
	F	189.70	0.66	1.31	0.69	191.42	191.42	0.85
VO_2 (l/min)	M	21.64	0.35	1.70	7.84	18.28	24.76	0.19
	F	22.36	0.44	0.88	3.94	21.13	23.20	−1.20
VO_2max (ml/min/kg)	M	34.83	0.67	3.30	9.48	30.43	40.87	0.51
	F	33.47	0.98	1.96	5.87	31.90	36.28	1.52
PCI (p/min)	M	88.28	1.33	6.50	7.37	75.84	101.02	0.26
	F	90.27	1.83	3.67	4.06	84.88	92.91	−1.76

N = 28, replicate = 5, M = male, F = female.

Table 2. Analysis of variance for PCI and EE.

Source	DF	SS	MS	F	P
Regression	1	1014.6	1014.6	2214.81	0.000
Residual Error	26	11.9	0.5		
Total	27	1026.5			

S = 0.676813, R-Sq = 98.8%, R-Sq(adj) = 98.8%.

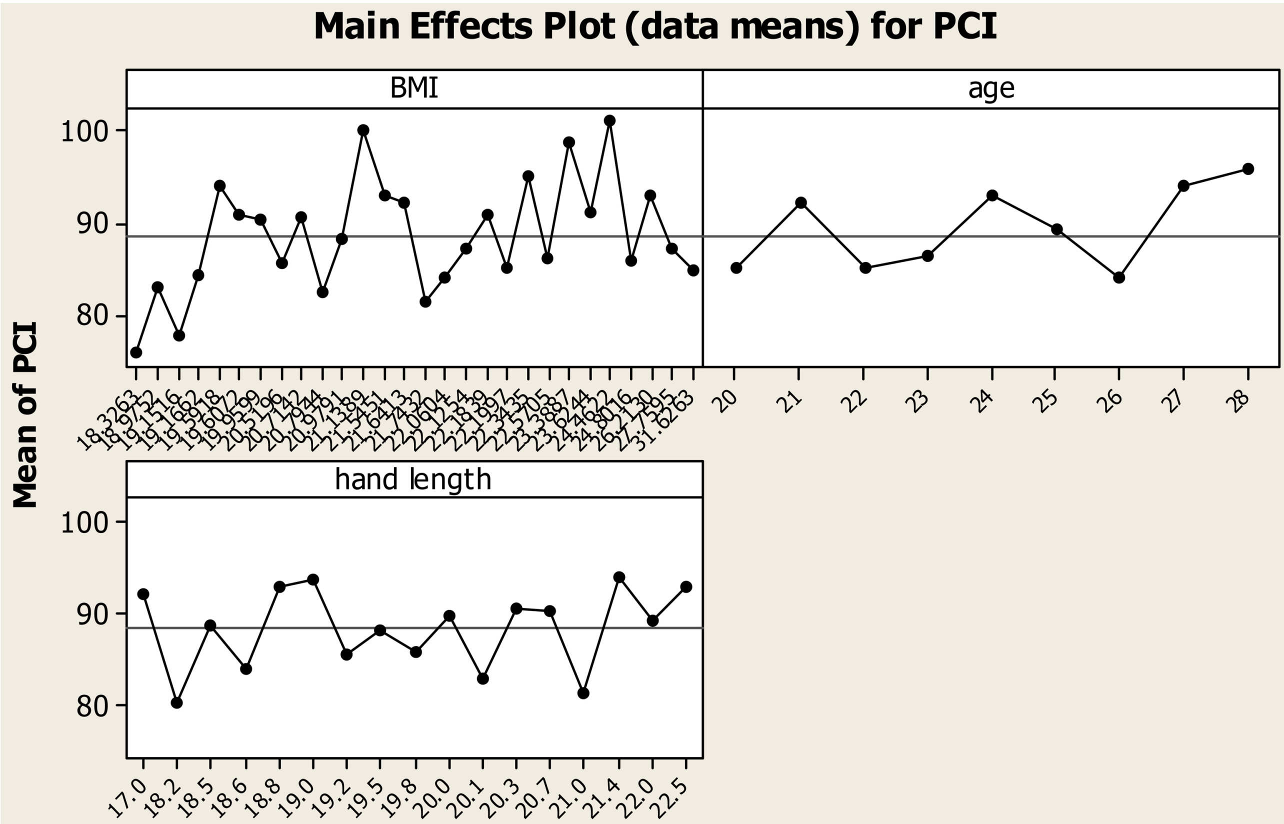

Figure 2. Effects of Anthropometric factors on physiological cost indices.

PC, the effect of operational factors on EE and the direct effect of operation on the subjects respectively.

Table 1 presents the values of the anthropometry, physiological and operational parameters of the subjects alongside with their sexes. The female subjects exhibited higher mean values of BMI (24.61 kg/m^2) and this corresponded to all physiological parameters except in aerobic power (VO_2max) where the mean value of male subjects is 34.83 ml/min/kg as compared to the females of value 33.47 ml/min/kg, this could suggest early incidence of fatigues in female operators as compared to the male ones. It is observed that all other anthropometry measurements have higher values in the favours of males as opposed to the female subjects. This may justify the fact that generally, the male subjects were taller while the female ones were weightier.

The operational parameters of stroke and pace made by the subjects during

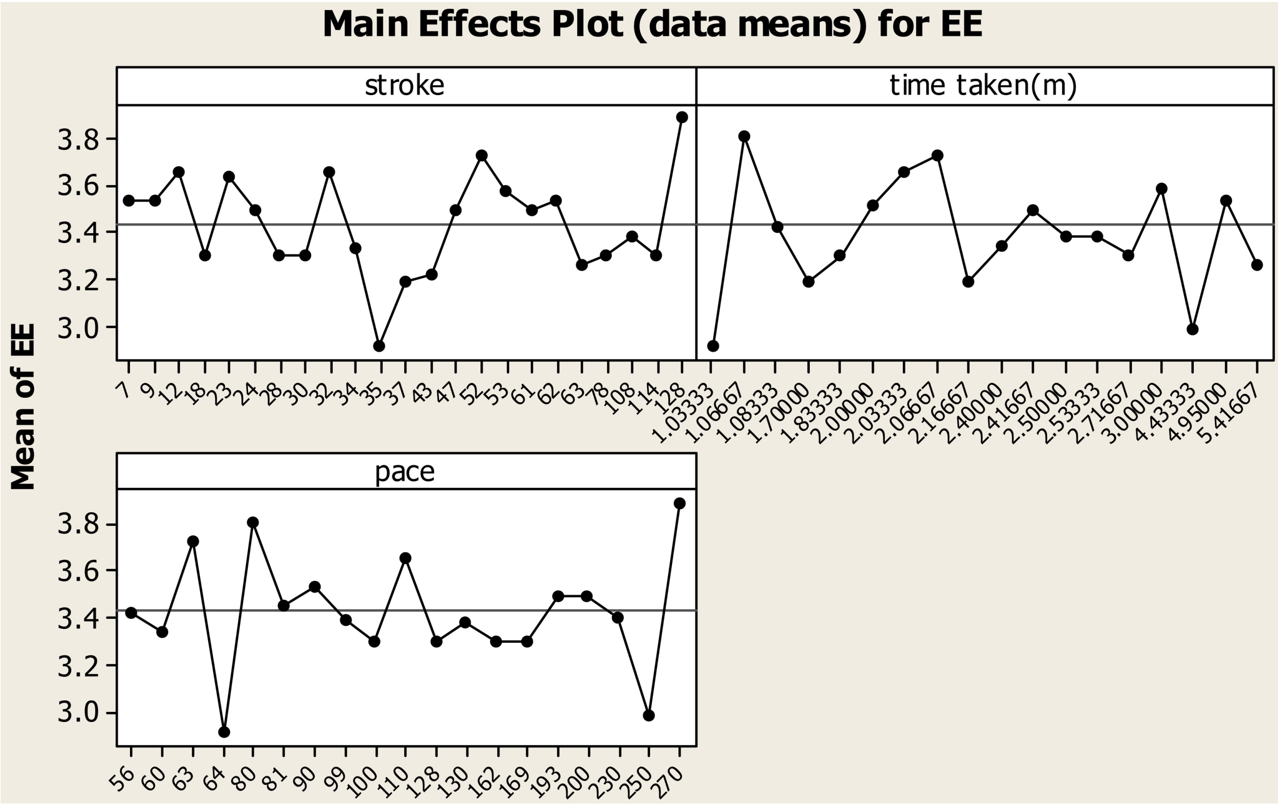

Figure 3. Effects of operational factors on expended energy.

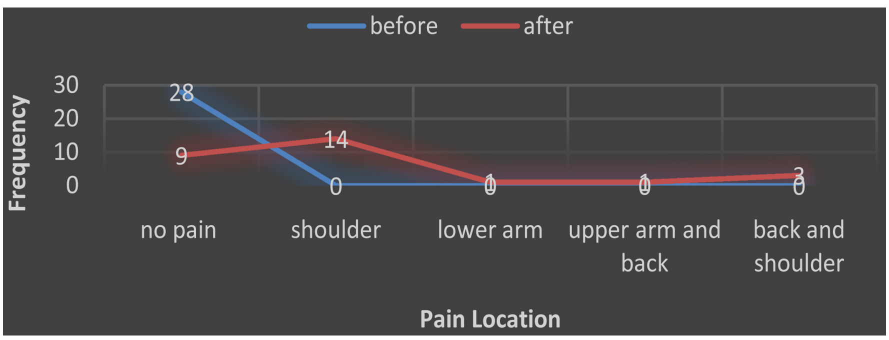

Figure 4. Varied body pain locations before and after spraying operation.

spraying operations ranged from 7 to 128 strokes and 56 to 270 paces; 12 to 62 strokes and 56 to 230 paces for male; female respectively. However, on the average the values for stroke and pace were higher in male, while the time taken to carry out the operation by the female subjects were higher; this further buttressed the resulted higher VO_2max and EE in male and female subjects respectively (Table 1).

Results showed that the coefficient of variations for all the parameters were normally distributed except for BMI in the female subjects, while stroke, time taken and pace were in both sexes, in that their values were greater than 10. The distributions skewed maximally at −7.76 (PCI) and 7.77 (Age, BMI) for female subjects, and minimally at −0.05 (elbow-finger) males and 0.05 (arm reach forward) females (**Table 1**).

The results presented in **Table 2** show the analysis of variance for physiology cost index (PCI) and body mass index (BMI) from regression analysis. The P-value at $\alpha = 0.05$ is 0.000, while $R^2 = 98.8\%$. This indicated that EE is good predictor for PCI. The regression equation for the relationship is given as; PCI = 1.97 + 25.2 EE.

Figure 2 shows the main effects of anthropometric factors of BMI, hand length and age on PCI. The differences across the means and the reference line indicated that, the effect of BMI upon PCI are large compared to the effects of the others, however, age has smallness effects on PCI, this could be as a results of ages of all the subjects that fall within the same category.

The main effects of operational factors of stroke, time taken and pace of the subjects on EE is as shown in **Figure 3**. Plot displays the response EE as affected by operational factors of the subjects. The effect of the stroke made by the subjects during spraying operation was the largest on EE as depicted by the means and the reference line, and this is respectively followed by pace and time taken to get the operation done (**Figure 3**). This may imply that expended energy (EE) is the direct function of physical activity performed, and indirectly dependent on time utilized.

Information on the expression of the subjects before and after the completion of the spraying operation was given in **Figure 4**. It was observed that all the subjects were without any body pain before the spraying operation; however majority indicated different location of body pains such as shoulder, back and shoulder, upper arm and back, and lower arm after the operation.

Figure 4 showed that only 9 subjects were without any body pains after the operation, while shoulder alone has the highest frequency of 14 subjects, followed by back and shoulder which is 3. The lowest on the frequency line are lower arm, and upper arm and back. This may suggest frequent utilization of analgesic to get well or absenteeism from operations by the operators.

4. Conclusion

The current study determined the impacts of Manually Operated Hand Lever Knapsack Sprayers (MOHLKS) on the body and physiological characteristics of the selected operators of age brackets 20 ≤ 30 years using field based assessment. The results demonstrated that the male operators expended lesser energy as well as lesser time in performing the operation as compared to female operators. Possibility of early incidence of fatigue is observed in female operators on the bases of higher body mass index and lower aerobic power. Shoulder was observed as body part that is susceptible to high risk of cumulative trauma, alongside with it are back, lower and upper arm. Future studies should attempt to examine larger area for the experiment simultaneously with a larger sample size of wider age range, with equal sample size for male and female operators and more time duration for the operation.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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