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Physiological Reactions of Push/Pull Exertion Mechanisms Demands on Workers for MMH Tasks in the Work Environment

Azodo Adinife Patrick[1], Ismaila Salami Olasunkanmi[1], Kuye Sidikat. Ibiyemi. and Dairo Olawale Usman

[1]Department of Mechanical Engineering, Federal University of Agriculture, P. M. B. 2240, Abeokuta, Ogun state
[2]Department of Agricultural Engineering, Federal University of Agriculture, P. M. B. 2240, Abeokuta, Ogun state
Email: azodopat@gmail.com

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Abstract

Manual Material Handling (MMH) tasks entail the physical application of considerable force to overcome a particular load or cumulative loads due to the heaviness during a workday. The push or/and pull forces engaged in MMH for goods transportation vary in the interaction the workers' has with the object being handled. The load mass conveyance activity is maximal in the work-in-progress due to the series and sequence processes involved. This study comparatively examined the effect of pull and push mechanisms during MMH tasks on the internal body function of the workers. The isokinetic technique used involved a load mass of 200kg conveyed through a distance of 400m. The data collection tools were a digital sphygmomanometer of model Omron M2 and a portable medGem device for internal body function; a digital professional (LCD) stopwatch (model PC-396) for the work process timing. The paired t-test data analysis showed that the duration for the MMH task through the distance using pull exertion mechanisms was significantly less than the push force at p< 0.05. This study also demonstrated a higher demand on internal body function variables using push exertion mechanism when compared to pull forces (p< 0.05).

1. Introduction

Manual material handling (MMH) activities in any organization such as manufacturing, production, warehousing, and construction is a full cycle of operations from the procurement of raw materials, include reception and storage before use, handling into and between processes and the handling of the finished goods, packaging, storage, and distribution. The handling mechanism involved when heavy loads masses are conveyed over a considerable distance is the exertion of pushing/pulling horizontal forces [1]. The horizontal pull or push exertion significance for the loads mass or equipment applicable for safe and efficient movement are affected by resistance dynamic, inertial force, speed and acceleration of the handling process as well as the feet friction/traction and physical strength of the workers [2]. The work tools for pushing and pulling exertion in loads mass transporting, or movement are manual carts, wheel-barrows, trolleys or any implement equipped with wheels or casters [2], [3]. The push or/and pull forces engaged in manual material handling for goods transportation vary in the interaction the workers' has with the object being handled. The distinction between the push and pull force mechanisms are specific to the identified controls attribute for the flow of goods, which is the orientation of the exertion [4]. The prevalence of pushing/pulling exertion method is of high frequency and a common approach of manual materials handling practices in the industrial workplaces of most developing countries [1], [3-7]. Despite the relevance of the push/pull force methods in manual material handling in most industrial sectors, they have received abruptly less attention compared to lifting and lowering manual material handling operations [8].

Industrial mechanization implementation of the conveyance tools for work physiognomies demands enhancement for a repetitive work operation, high intensity and duration, like every other MMH task results in a chronic health challenge burden and susceptibility to long-term health effects such as musculoskeletal complaints and disorders [9]. The mechanization of MMH jobs, according to the study, leads to the prevalence of musculoskeletal illnesses in the workplace [9]. Several MMH jobs requiring pushing and pulling exertions were listed by Agrawal et al. [3] as contributing to physical workload and musculoskeletal symptoms in employees affecting the low back and upper extremities. The load mass conveyance activity is maximal in the work-in-progress due to the series and sequence processes involved. The MMH tasks, individually or collectively, impose health challenges to the exposed workers if not properly managed. The maximization of work tools to perform and complete tasks in light of optimal productivity and improved efficiency is the amount of material handled through reducing wasted effort and time [2].

Agrawal et al. [3] identified the methods for measuring and predicting workers' capability during horizontal pull/push force exertion in MMH as isometric and isokinetic strengths. The isometric strength assessment test was utilized in several studies which have controlled limits concerning time for determination of the worker capability during horizontal pull/push force exertion in MMH [3], [4], [10], [12]. Mital and Faard [13] adopted the isokinetic pull and push strength test approach in their study in determining the physical strength pull/push force exertion in MMH. However, these works were laboratory tests. Majumder et al. [1] study investigated the effects of unidirectional and bidirectional torque on the physical strength generated as well as sustained by the subjects. The working posture effect on isokinetic pull and push strength of males was assessed by Mital and Faard [13]. Other studies that assessed dynamic push/pull forces looked at the effect of surface type, wheels width, wheels diameter, and wheels direction the type of conveying equipment used such as manual carts, wheeled cages, and two-wheeled containers [14-16]. The maximal strength application pulls and pushes strength in the vertical direction was studied by Hendrikse and Smith [17] and Weston and Marras [18]. In other studies, anthropometric parameters were employed in the horizontal push/pull force exertion investigations to predict maximum isometric horizontal strength exertion [19], [20]. The load mass or equipment and the orientation of applied force are two significant parameters found by studies that affect workforce health and productivity in MMH horizontal push/pull force exertion [2]. Darcor and Ergoweb [2] and Agrawal et al. [3] studies demonstrated that forces exerted during push activities are higher than pull forces [2], [3], [21], [22]. Contrarily, the findings of Davis and Stubbs [23], Kumar et al. [6], and Seo et al. [24] found that the motion imparted to objects during pull requires higher pull strength than the motion imparted during the push. Pyke and Cohen's [25] review pointed out that the distinction between pull systems from push systems is not well understood. It is, therefore, necessary to examine the internal body function push and pulled forces during manual material handling as a surrogate marker of physical activity level for a physiological variable that informs an individual's physical work capacity.

The workforce demand in manual materials handling tasks requires adequate control of the whole work process, usually among the available alternatives for efficiency and cost-effectiveness considering time and workforce health. This implies that any ergonomics intervention in the work environment viewed in light of work process effect on productivity, and improve efficiency must consider especially the reduction of force exertion necessary task completion and time. Therefore, this study comparatively examined the effect of pull and push mechanisms during MMH tasks on the internal body function of the workers.

2.0. Materials and method

The participants studied were three hundred and ninety (390) males of 20-39 working-age range randomly selected from Abeokuta, Nigeria. The participants were chosen based on an unbiased assessment for deformities or compromised integrity of the subjects' body size and health status, which could affect their physical fitness performance. These were covered in the body anthropometry assessment. Objective research technique used for data collection involved physical measurement of the body characteristics of the subjects and intensities of physical activity through the recording of the physiological reactions of the respondents to a physical effort (changes of the frequency of heart contractions, blood pressures (systolic and diastolic), the capacity of respiratory gas intake (VO_2). The isokinetic technique was employed since most manual material conveyance tasks in industrial sectors, especially in developing nations, are dynamic and entail pull or/and push exertion. The MMH conveyance task in the work environment, loading, offloading, clearing the production floor and storage, is characterized by moving load mass of similar weight per time through a distance. Now considering that the human strength varies with many task-related factors, the load mass used was of a 200kg weight conveyed through a distance of 400m. The working distance of 400m employed in this study reflected the dynamical effort of repeating nature as the subjects had break periods between the conveyance work processes. Because the push/pull forces in the workplace are unlikely to remain constant during the workday, start and finish locations were established, with the subjects pulling or pushing the load mass to the end without any scheduled rest periods to avoid muscular fatigue. However, the orientation of exertion (pull or push force) was repeated by each participant for the conveyance work process on different days within the same daytime interval. The conveyance duration for the pull or push force orientation of exertion was monitored. The baseline information obtained for comparison at the end of the pull and push application considered the participant's heart rate, blood pressures (systolic and diastolic), and VO_2max. These physiological test data obtained from each of the participants were after a two- to three-minute rest break in a seated position before and after the work process. The participants were adequately informed about the purpose of the study and the role they needed to play. Data were obtained from the contacts who agreed to participate. Participation was voluntary though refreshment was offered at the end of the work processes.

Design instrumentation for data collection in the study were

i. Digital sphygmomanometer of model Omron M2 (OMRON Healthcare Europe B. V., Netherlands) was used for heart rate and blood pressure level monitor (Figure 1).
ii. The medGem is a handheld portable indirect calorimeter assessment device. The medGem is used in conjunction with a nose clip and a single-use mouthpiece to measure oxygen consumption (VO_2) by monitoring the inspired and expired airflow (Microlife Medical Home Solutions, Inc.)
iii. A digital professional (LCD) stopwatch of model PC-396 (Shenzhen super deal Co, Ltd, China) was used for recording the duration of the time interval for the work characteristics during the physical work activity assessment (Figure 3).
iv. The stadiometer used is detectoprodoc professional doctor scale of model PD300DHR (Cardinal scale manufacturing company, USA). The stadiometer measure the height, weight and can accurately calculated the body mass index by pressing the required button (Figure 4).
v. A locally constructed two-wheeled cart with load mass of 200kg containers in it (Figure 3).

Figure 1. Digital sphygmomanometer

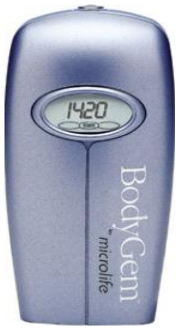

Figure 2. BodyGem

Figure 3. A digital professional stopwatch

Figure 4. Stadiometer

Figure 5. 200 kg load mass

The physiological response data during the physical work activity for the cart pull was compared to that of the cart push body reaction. The physiological responses (heart rate, VO_2max, systolic and diastolic blood pressure) for pull and push exertion approaches were analyzed on SPSS version 20 package using a paired t-test with a p-value of 0.05 for the significant difference between the pull and push MMH tasks.

3.0. Results and discussion

Table 1 presents the age and the body anthropometry characteristics descriptive statistical analysis results in mean, standard error of the mean, standard deviation, minimum, maximum, 5th and 95th percentile format for the participants. The mean age of subjects was 28.11 ± 5.12 years. The body anthropometry characteristics data obtained and analysed were the core elements of human anthropometry, height, weight, and body mass index (BMI). The body mass index value, which is dependent on the body weight, and height of an individual, is a valuable indication for the overall fitness assessment. The range of the body mass index (BMI) of the subjects in this study was 16.20 - 31.60 kg/m^2 with an average mean value of 23.02 ± 2.51 kg/m^2 (Table 1). The average mean value of body mass index obtained from the subjects fell under the normal weight range categorized by the world health organization which indicated fewer chances of complications and health risks during the physical activity test. This is because the human sensing and performance capabilities are in part related to the human body physical characteristics (body weight, and height of an individual) [26-27].

Table 1. Age and the body anthropometry characteristics of the study participants (n = 390)

Assessed variables	Mean ± SD	SEM	Minimum	Maximum	Percentiles	
					5th	95th
Age (years)	28.11 ± 5.12	0.26	20.00	39.00	20.00	35.45
Height (cm)	167.06 ± 6.40	0.32	150.00	186.00	154.55	177.00
Weight (kg)	64.05 ± 6.01	0.30	50.00	82.00	56.00	74.00
BMI (Kg/m^2)	23.02 ± 2.51	0.13	16.20	31.60	19.20	26.99

The participants were involved in pull and push forces. The study focused on the effect of the applied force mechanisms for controlling goods or the flow of materials in the workplace. This is because the analysis of the baseline information obtained from the participants compared using independent *t*-test showed no statistical difference for all the internal body function response variables (heart rate, systolic and diastolic blood pressure, and VO_2max). The average effect of the heart rate of the subjects on the time taken to accomplish the work tasks analysed using linear regression analysis (*r*-value) which was a correlation analysis between the heart rate and the time taken to accomplish the task was 0.87 which was a high positive correlation significant at $p < 0.05$ (Figure 1). This implies that the increased in the heart rate of the subject effects of time of accomplishment.

The physiological data obtained for the MMH task using pull exertion was compared with the internal body reaction caused by push force for the impact analysis after involvement in physical work activity. Paired samples *t*-test was used to compare the two independent internal body function response variables (heart rate, systolic and diastolic blood pressure, and VO_2max) for the applied force mechanisms (push and pull) attempt to overcome resistance in the control of the material flow. From the analysis carried out, the paired *t*-test result for the time it took for the participants to move the load mass of 200kg through a distance of 400m showed a large *t*-score (t = 3.440, df = 390) which was an indication that the groups are different. The *p*-value of less than 0.05 (p = 0.001) showed that internal body function response variables for the push and pull force mechanisms applied to overcome resistance in the control of the material flow is significant. The heart rates and maximal oxygen uptake also showed similar results significant at p = 0.05. The paired t-test result for the systolic and diastolic blood pressures were t(-4.128), df = 389, and p = 0.000 and t(16.377), df = 389, and p = 0.000, respectively (Table 2). Thus, there was a significant statistical difference for all the internal body function response variables (heart rate, systolic and diastolic blood pressure, and VO_2max) for the between pull and push effect of the applied force mechanisms for controlling goods or flow of materials on the workplace.

Table 2. Paired sample t-test for push and pull applied force mechanisms for controlling goods or flow of materials on the workplace

Work characteristics		Descriptive statistics			*t*-test for equality of means		
Orientation of exertions	Assessed variables	N	Mean ± SD	SEM	*T*	*Df*	*p*-value
Push	Time	390	994.14 ± 192.02	9.71	3.440	390	0.001
Pull		390	961.36 ± 29.54	1.49			
Push	Heart rate	390	85.47 ± 8.23	0.42	36.240	389	0.000
Pull		390	94.69 ± 5.87	0.30			
Push	VO_2max	390	43.96 ±	0.30	-8.623	389	0.000
Pull		390	45.72 ± 5.43	0.27			
Push	SBP	390	135.63 ± 17.26	0.87	-4.128	389	0.000
Pull		390	137.91 ± 11.55	0.58			
Push	DBP	390	92.78 ± 6.19	0.31	16.377	389	0.000
Pull		390	88.57 ± 2.13	0.11			

SBP = Systolic blood pressure, DBP = Diastolic blood pressure, SEM = Standard error of mean, SD = Standard deviation

4.0. Conclusion

Human strength varies with many MMH task-related factors, including horizontal distance, especially from the orientation of exertion and speed. Studying the details of a task should accommodate certain design features that can influence equipment utilization procedure considering human variability and the approach used in the world of work. There is a need for generic, safe techniques and interventions for improving job quality, comfort, health, safety, and productivity. The efficient application of the ergonomic principle for a repetitive task requiring force exertion through a working distance assessed in this study showed that in the conveyance of load masses in the work environment, pulls exertion is advantageous when compared to push force in terms of work duration and internal body function demand.

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