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Physiological and psycho–physiological approaches for maximal carrying load estimation

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Abstract

The present study was conducted on eighty-two scaffolders, which in their daily schedule performed various carrying load activities. The physiological and psycho-physiological approaches were used to determine the maximum carrying load. The scaffolders were divided into 21-30 years, 31-40 years and ≥41 years age groups. In the physiological approach, the experimental data were collected through field and laboratory studies, which included maximum oxygen intake rate, scaffolders heart rate (HR), and its variability. In the psycho-physiological approach, random loads were assigned to identify the load carrying limits of scaffolders belonging to different age groups. The average working HR varied from 125-148 bpm, and the average maximum oxygen intake rate was 1.69 (0.17) l/min, 1.64 (0.23) l/min, and 1.51 (0.19) l/min, respectively, for scaffolders of selected age groups while carrying scaffold poles or boards, guardrails and ladders. The electromyography (EMG) results during load carrying activity in head mode ($p<0.02$) and shoulder mode ($p<0.0.5$) found that the trapezoid(r) muscle displayed a gradual increase in EMG values with increased load. In conclusion, maximum load-bearing capacity was estimated for scaffolders of selected age groups using the physiological and psycho-physiological approaches.

Keywords: Heart rate, Physiological, Carrying load, Psycho-physiological, EMG, V_{O2max}

1. Introduction

The main tasks of scaffolders are to erect and remove large scale scaffolds. But heavy load handling, for instance, scaffolding poles and boards, guardrails and ladders is one of the critical activities among these tasks [1]. Obviously, on construction sites, scaffolds are needed to raise construction workers and their materials to higher levels. Nearly 2.5 million construction workers depend on scaffolding for their work. According to the Bureau of Labor Statistics, there are around 4,500 scaffolding associated accidents and 60 deaths per year [2]. Scaffold erectors and dismantlers are at particular risk, as they work on scaffolds before the complete installation of ladders, platforms, planks, and guardrails. Injuries common to scaffolding accidents are broken bones, particularly broken legs, ankles, feet, arms, hands, spines and various types of musculoskeletal disorders (MSDs) owing to manual handling of scaffolds that are beyond the scaffolders' load capacity limit.

Loading the body within one person's adaptive capacity can improve tissue strength, but loading over and above adaptation and relieving capabilities of a person can lead to fatigue failure [3], or early bone and soft tissue degeneration [4]. There is substantial evidence in support of the above statement that the physical stress associated with heavy material handling acts as a risk factor for lower back pain [3, 5] as well as for other muscles such as neck, shoulder, calf etc. [6, 7]. However, very few studies have specifically examined scaffolders' job in emerging nations and have implemented suitable methods for scrutinizing their general health or MSD associations.

For manual material handling (MMH), the researchers recommended physiological and psycho-physiological methods as the most prevalent approaches [5, 8, 9]. In the physiological study, oxygen uptake (V_{O2}) and heart rate examination are mostly conducted in the carrying load analysis to exclude the physiological strain [10]. The physiological studies conducted by researchers [11-13] have indicated that the experimental work duration of 20-30 mins is sufficient to estimate the appropriate workload for 8 or 12 hours per day. The research [10] shows that the walking speed carrying load significantly influenced both heart rate and oxygen uptake carried as well as increased the EMG of the muscles. The EMG results of the researchers [14, 15] have also supported the effect of carrying load on muscle activity.

Many researchers [16-18] have suggested that the psycho-physiological approach is a reliable method in assessing the perceived exertion during MMH. In the psycho-physiological experiment, the task is generally initialized with a random load weight and the subject is asked to adjust the load based on their choice such that the load will be acceptable for 8 hrs in repetitive handling operation [19]. Further studies [13, 17, 20-22] have mentioned that participants could determine the maximum acceptable work load limit within shorter adjustment period to allow the participants to monitor their own feelings and adjust the load weight.

The workers involved in unorganized industry in India are continually over-exhausted without any law protection. These workers are temporarily employed on a daily basis by labor contractors. The workforce is abundant, low-skilled, and easily accessible, which

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shows the high unemployment rates that make them vulnerable to exploitation. They work without medical and other benefits for low wages. It's more important for them to get work; hence, they are concerned about the hazards involved. Poverty, poor wages, and large family must be supported by the wage earner, which further worsen the plight of the ill-fed worker. There has been no improvement in the situation of unorganized workers since independence. Further, no record of their health or industrial accidents is maintained.

Upon recognizing the threat of MMH tasks, several countries have placed some weight limitations for manual lifting and/or carrying. Additionally, emphasis is placed on administrative and personal interventions to improve handling of loads that minimize potential for injury risk. In India, some ceiling on the weight to be carried by an individual must be prescribed to ensure the health, safety and well-being of workers.

Moreover, almost no active consumer groups in India regularly comply with regulations on the safety, health, and welfare of workers. They live in slums and poor environmental conditions, and majority of them are underfed [23]. The workers have to work under the scorching heat of the sun without using any personal devices for protection.

1.1 Study purpose

For lifting load analysis, the researchers also used the National Institute for Occupational Safety and Health (NIOSH) equation, which is mostly applicable in Europe and North America; hence, the applicability of NIOSH equation across countries is at risk [22]. Further, the current study is on load carrying activities, wherein the NIOSH lifting equation is not valid. In this context, this research was conducted with the aim of evaluating the maximum acceptable load that the Scaffolders could carry for 8 h through a physiological and psycho-physiological study.

2. Methodology

2.1 Subject selection

Eighty-two scaffolders engaged in scaffolding activities were randomly selected for the study. However, very few female workers were observed in scaffolding activities because it involved heavy load carrying activity. The study was therefore carried out only on male workers. The informed consent was obtained from each subject in their local language and also approved from the ethical committee of DEI. Figure 1 illustrates the scaffolders involved in various activities. Mostly scaffolders working on scaffolding sites were found to be in the age groups of ≥21 years. Table 1 illustrates the physical characteristics of the subjects.

Figure 1 Scaffolders engaged in various activities

Table 1 Scaffolders' physical characteristics

Variables	Age groups (years)		
	21-30	**31-40**	**≥41**
Age (Year)	25.7 (3.2)	34.7 (3.6)	45.2 (4.1)
Weight (kg)	61.3 (4.7)*	61.7 (3.2)	60.4 (2.6)*
Height (cm)	168.3 (4.1)	168.4 (5.1)*	167.9 (4.1)
Fat (%)	26.3 (0.9)	26.7 (1.4)	26.4 (0.7)
Lean body weight (kg)	33.8 (1.4)*	34.3 (1.3)	34.6 (6.1)
Ponderal index	25.3 (0.9)	25.4 (0.71)	25.4 (0.8)*

Note: Values are presented as M(SD).
* Statistical variation between the age groups of the scaffolders. χ^2 test used with a significance level of $p<0.05$.

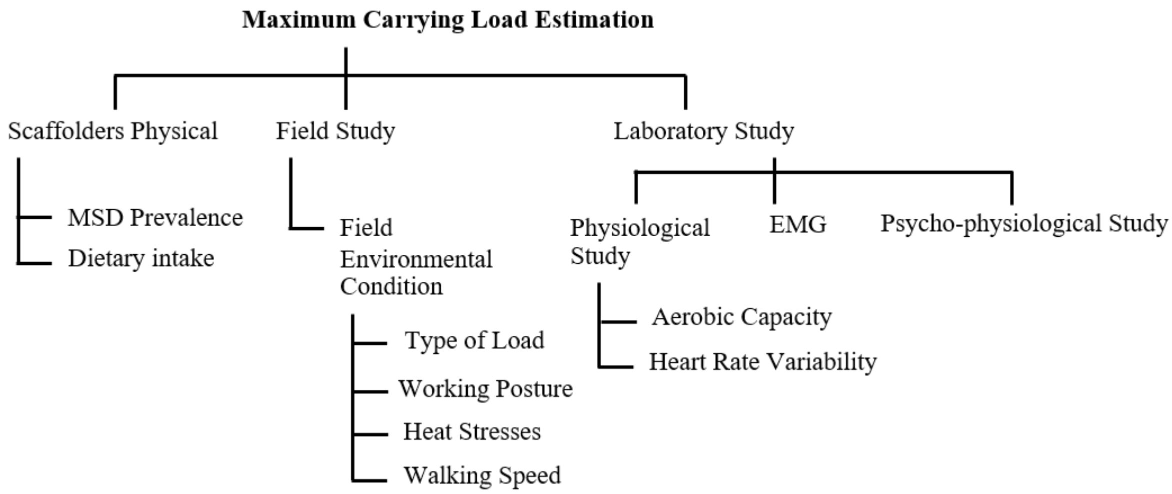

Figure 2 Study flow chart

2.2 Scaffolders physical health

Figure 2 depicts the study flow chart used to estimate the maximum carrying load.

2.2.1 Musculoskeletal disorders (MSDs) prevalence

The scaffolders carried the load manually; so, they also suffered from some kind of body pain. The prevalence of musculoskeletal disorders (MSDs) among scaffolders was calculated and shown in Figure 3 with the questionnaire analysis. The scaffolders complained about feeling discomfort and body pain. Upper back pain appeared to affect predominantly 78%, 84%, and 91% of scaffolders aged 21-30 years, 31-40 years, and ≥41 years, respectively, followed by feeling of discomfort and pain in the leg region (68%, 82% and 90%), neck (71%, 74% and 87%), and shoulder (47%, 54% and 72%).

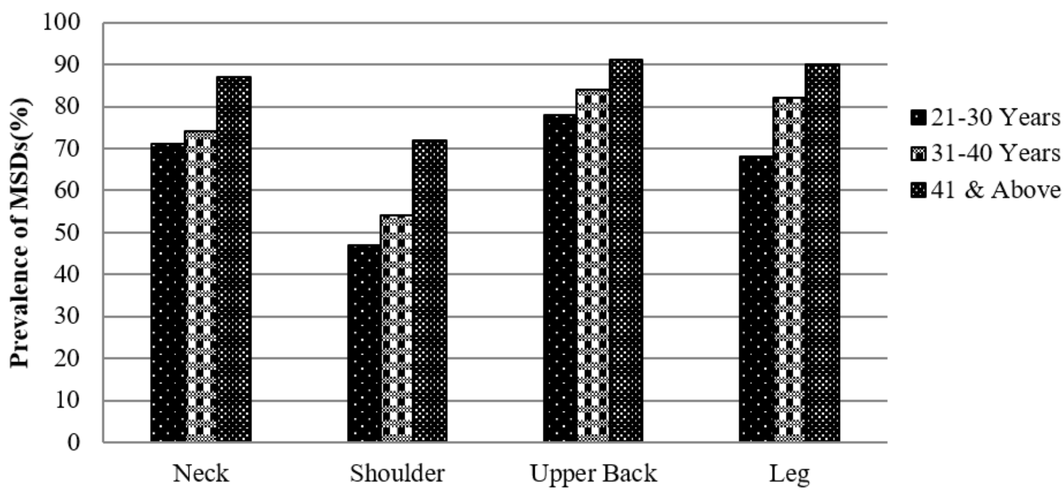

Figure 3 MSDs prevalence among scaffolders

The prevalence of MSDs in scaffolders shows the importance of the current study that aims to protect scaffolders from different MSDs through maximum load estimation.

2.2.2 Dietary intake

Twenty-seven subjects involved in various scaffolding activities were selected randomly for the dietary intake study. Indian food standard values were used to calculate the nutritional and calorific values of the food [24].

2.3 Field study

2.3.1 Field environment condition

In order to find the environmental heating stresses, various parameters were measured like relative humidity (RH), dry and wet bulb temperature, air velocity and globe temperature with the help of an environmental kit. Readings were noted in the laboratory and in the field at odd times of the day. The study revealed the scaffolders were working under conditions of positive heat stress, which increases the risk of occupational injuries [25]. Moreover, the construction sites' work terrain was very hazardous, thus creating problems in the worker's comfortable work and movements.

Based on the conditions of the scaffolding site, the scaffolders average walking speed measured on the treadmill machine was 3.9 km/h, 3.7 km/h, and 3.3 km/h with a load range of 10-50 kg. However, to prevent excessive fatigue and muscle pain during laboratory tests, the walking speed was set at 2.5 km/h for selected age groups [26, 27]. Scaffolders had to work for approximately 10 hours/day and travel a distance of about 3024 meters with heavy load.

2.4 Physiological study

To determine the kind of stresses developed during various activities and to monitor the working heart rate (HR) at the construction sites, a waist-mounted electrocardiogram device also known as “ECG” named LAB Holter 12.0 Plus (Biomedical, USA) was used. HR of each worker was monitored for three successive trips. The first measurement of the HR was done at the starting of the trip; subsequent to this, the HR was measured and analyzed on the final destination, following which it was again measured at the starting point. The average HR at rest, start and return were also taken into account.

2.4.1 Aerobic capacity

Scaffolders from various age brackets were chosen randomly from a specific working population for determining maximum aerobic capacity. The open circuit method was used to assess the maximum oxygen intake. During each carrying load, the expired air was collected in a 50 liters Douglas bag. The workers were not supposed to carry the weight of the bag and the accessories like 2-way stopcock and hosepipe, so, they were kept on the side table. A paramagnetic oxygen analyzer was used to determine the oxygen content present in the expired air. Used to determine the heart rates, Beckman Dynograph was used for picking the ECG signal by Ag-AgCl surface electrodes. Subsequent to this, the data analyzer was supplied with the output from Dynograph, which provided the continuous cardiac HR monitoring.

2.4.2 Measuring the HR variability

The working scaffolders of the selected age groups were picked at random for the determination of the HR variability using ECG device named LAB Holter 12.0 Plus (Biomedical, USA)., The physical health of the scaffolders were verified both before and during the experimental study by examining their resting HR and blood pressure (BP), which showed that they had no medical problem. Time domain analysis system was used to find the HR variability. For measuring the HR variability in various postural modes, the subjects were instructed to carry loads ranging from no load to 50 kg and walk on a treadmill machine at a fixed speed of 2.5 km/h with electrodes placed on them. Subjects performed the mentioned task for approximately 30 min. Furthermore, the ECG Holter report recorded a standard deviation of all the normal to normal R-R intervals (SDNN). Figure 4 illustrates the placement of electrodes on scaffolders while measuring HR variability.

Figure 4 Placement of electrodes while measuring HR variability

2.5 Electromyography (EMG)

Load carrying often required the involvement of different muscles, so in the current research, the EMG technique was used to learn the involvement of different muscles related to varied modes of load carrying. The muscles needed to be studied were selected either by palpating each muscle or by activating the muscle of interest. The EMG signals were recorded using the Beckman Dynograph (model R612, six channel) for three different muscles, viz., neck(r), trapezoid(r) and errector spinae(r), as those were primarily involved in load carrying [28]. The EMG setup is depicted schematically in Figure 5.

Figure 5 Schematic presentation of the EMG setup

EMG signals from different muscles were collected using Ag-AgCl surface electrodes attached to the skin. The strength of the signals expressed the degree of muscle involvement; hence, the degree of muscle load could be measured from the EMG. The higher signal amplitude measurements usually indicated higher muscle activity. Therefore, the EMG signs of fatigue indicated muscle exhaustion. Local muscle exhaustion [29], involving weakened muscles, fatigue and pain and variations in EMG signals, was caused by high rates of muscular inference. Both the changes were closely connected to the process of exhaustion. Figure 6 shows the positioning of the electrodes on the muscles.

Figure 6 Placement of electrodes on muscles

2.5.1 Preparation of the subject for EMG

The desired muscles were first identified over the skin surface for developing the contracture and were marked by pen. The muscles site was then cleaned with cotton soaked in alcohol to remove the dead superficial cells of the ectodermal layer. After allowing the skin to dry, emery paper was used to rub the skin for further removal of highly resistant cells. The site was again wiped with alcohol and allowed to dry. A double-sided adhesive tape was placed on the clean area to hold the electrode in position. Thus, the pair of electrodes were placed on each muscle with an inter electrode spacing 1-2 cm (Figure 6). Each electrode was then filled with conductive jelly and connected to the Dynograph. The impedance between the electrodes being an important factor was measured, as it affected the quality of the signal. Care was taken that the resistance within two electrodes lies between 1-3 kΩ. Altogether five pairs of electrodes were fixed on the respective muscles as mentioned earlier. As per requirement, earth connections were given to the ear lobe of the subjects to eliminate external electrical artifacts.

The results of Dynograph were saved in a 7-ch TEAC IM recording device. The signals stored on this device were then analyzed with the use of an Analogic 610 Signal analyzer for the Root mean square (RMS) values.

2.6 Maximum carrying load estimation

The randomly selected scaffolders were brought to the laboratory to determine the maximum carrying load. The subjects were told to report at 9:00 a.m. and they were asked to take rest for about 10-20 mins for avoiding the physical and emotional influence on the HR. During the entire experiment, HR was monitored in all working conditions. For every minute, the samples were recorded and studied. The subjects were informed of the experimental protocol before the experiment and were briefed about the tools. The relaxing oxygen intake and the HR of each scaffolder was observed. The study reports found that no external clinical symptoms existed in the subjects and were in good physical condition. The experiment protocol was mentioned in the following steps:

Step 1 - The field study was conducted to get the information for the laboratory study on the type of load, work posture, working environment, work terrain, and walking speed. The field study was conducted to.

Step 2 - The basic and general data of the subjects such as their hemoglobin level, pressure of blood (mm of Hg), height, oral temperature, weight and skinfolds were noted with the help of instruments and devices like Haemometer, thermometer, anthropometer, BP apparatus (Hg-manometer type), stethoscope and Lange skinfold caliper.

Step 3 - While conducting the lab experiment, the subjects were provided with identical shape, dimensions, and size of different carrying loads as the one which were used at the scaffolding sites (field study).

Step 4 - The walking speed was controlled with the help of a treadmill. In head and shoulder mode, the subjects were guided to carry each load varying from 0-50 kg for 20 mins. First, the reading was taken at "0" load followed by the reading with a load of 10 kg. Subsequently, the experiment was carried out with an increase of load of 5 kg to a load of 50 kg. The loads were administered randomly at a speed of 2.5 km/h [26, 27].

Step 5 - After a cycle of each load, workers were questioned regarding any muscular fatigue and the psychophysical scaling was done to figure out the answers in respect of weight heaviness.

Step 6 - Throughout the experiment, HR was checked and O2 intake was observed at the 5th min of each load.

Step 7 - The recovery of 10-15 mins and the rest of 30 mins followed each load carrying activity. If after 30 mins of rest, the HR of the subject had not descended to the rest level then more resting was provided to avoid any muscle fatigue.

Step 8 - After carrying the loads for about 20 mins, the scaffolders were questioned about the carrying mode posture and maximal load.

Step 9 - After knowing the maximum load limit through the physiological and psycho-physiological study, the maximum load estimation was done.

2.7 Statistical analysis

In case of continuous variables, the mean and standard deviation (SD) values were calculated. The inter-group analysis was carried out with χ^2 test (categorical variables). The distribution of the data for most variables was normal ($p<0.05$). The data was analyzed using the SPSS version 20.0 designed for Windows operating system.

3. Results and discussion

The physical attributes of the scaffolders show that the body weight ($p<0.05$), height ($p<0.02$), lean body weight and ponderal index ($p<0.001$) were significantly different. The frequent load carrying postural modes was found to be head and shoulder during the field experimentation. The body pain questionnaire revealed that intense pain was felt in various body parts like upper back, neck, leg and shoulders.

The nutritional study finding indicated that the average energy consumptions in the scaffolders were significantly lower compared to the heavy workloads. The average hemoglobin content in them was also found to be 9.7 gm/dl, which was lower than the average population (13.8 to 17.2 gm/dl) [30]. The findings of the nutritional study showed that the scaffolders were more prone to injuries; thereby revealing the importance of maximum load estimation for scaffolders.

3.1 Physiological stress

The calculation of this stress was done in the scaffolders during the activity based diverse parameters like peak and average HR and maximum oxygen consumption rate (V_{O2max}). The resting HR of each scaffolder was evaluated from his ECG recording. Figure 7 shows the average HR for starting, working (carrying load), returning and resting in various postural modes on the field. It was predicted that the average working HR varied from 125 bpm to 148 bpm while carrying scaffold poles or boards, guardrails and ladders. The resting HR varied from 74 bpm to 82 bpm and the starting HR ranges from 102 bpm to 107 bpm for all work immediately before restarting after one cycle was completed.

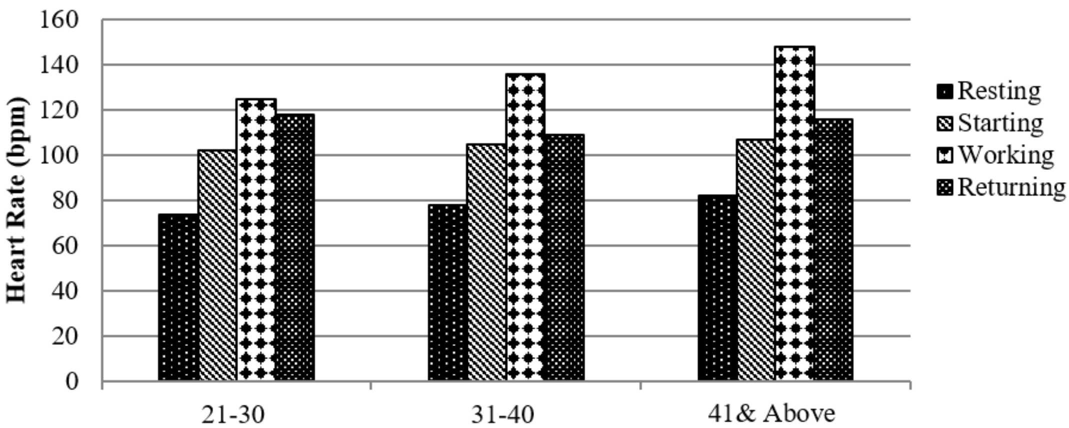

Figure 7 Average HR for resting, starting, working (carrying load), and returning (bpm)

From Figure 7, this is clearly shown that all the subjects involved in scaffolding worked with cumulative physiological stress owing to insufficient recovery time, which was also supported by complaints of higher body ache rates and tiredness at the end of the day. The subjects also supported that the body pain persisted even on the subsequent day.

According to Sen's [31] classification, the physiological workload of scaffolders involved in carrying load activities could be graded from the category 'moderately' to 'very heavy' based on average working HR.

3.2 Lung function test (LFT)

The LFT was used to determine that all subjects had no pulmonary disorders using a spirometer (COSMED, Italy). The forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) were calculated and the readings were observed in the standing posture. Average FEV1 and FVC levels of the spirometers were respectively 2.3(±0.3) liters and 2.7(±0.5) liters. The FEV1/FVC relationship given in Forced Expiration [32] depicted that the subjects were not affected by any pulmonary problem as the FEV1/FVC normal values were more than 80%.

3.3 Maximum aerobic capacity of scaffolders

Table 2 indicates the average maximum oxygen intake rate was 1.69(0.17) l/min, 1.64(0.23) l/min and 1.51(0.19) l/min for scaffolders of the selected age groups, respectively. In this study, the fitness level of all age groups of scaffolders was categorized under 'excellent' by Saha [33].

Table 2 Maximum aerobic capacity

Age group (years)	Age (years)	Body height (cm)	Body weight (kg)	HR max (bpm)	V_{O2max} (l/min)
21-30	26.4 (3.1)	165.5(4.2)	59.6(3.5)	190.7(8.7)	1.69(0.17)
31-40	33.8 (4.1)	165.2(5.2)	60.4(3.4)	186.3(10.3)	1.64(0.23)
≥41	43.1(3.0)	164.8(3.8)	59.7(4.2)	172.8(11.4)	1.51(0.19)

Note: Values presented as M (SD)

3.4 HR Variability

The HR variability of scaffolders during load carrying on head and shoulder mode is illustrated in Table 3. The standard HR variability values (SDNN) were within the group of:

- 0-50 - High Risk
- 51-100 - Medium Risk
- 101-150 - Low Risk

It was accounted that the HR variability values of scaffolders (SDNN) move from low to high risk in both the head and shoulder mode with increase in the load. The effect of load on HR variability and the increase in age also showed the same response. The results of this study were also confirmed by the results of Van Ravenswaaij [34], which stated that the major influencers of the HR variability were factors such as age and posture of the subject while carrying loads.

Therefore, to keep the value of HR variability in the category of low and medium risk, the maximal load carried by a scaffolder should be controlled.

Table 3 Mean HR variability (SDNN) while carrying load in head and shoulder mode

Load (kg)	21-30 years		31-40 years		≥41 years	
	Head mode	Shoulder mode	Head mode	Shoulder mode	Head mode	Shoulder mode
0	121	121	116	116	108	108
10	114	107	104	99	86	89
15	103	100	92	84	79	70
20	94	94	86	71	72	51
25	88	76	78	61	52	45
30	82	47	57	45	43	38
35	57	–	50	–	39	–
40	46	–	43	–	37	–
50	39	–	37	–	32	–

Note: SDNN = standard deviation of the normal R-R interval.

3.5 Physiological cost of work of scaffolders

The scaffolders of mentioned age groups were selected at random to calculate the physiological cost of work. Tables 4 and 5 illustrate scaffolders' cardiac demand and V_{O2max} while continuously carrying load for 20 mins on head and shoulder mode. The scaffolders in shoulder mode were unable to carry load up to 50 kg, so the data was only collected from 0 kg load to 30 kg load.

Table 4 HR (bpm) of Scaffolders while carrying load in head and shoulder mode

Load (kg)	21-30 years		31-40 years		≥41 years	
	Head mode	Shoulder mode	Head mode	Shoulder mode	Head mode	Shoulder mode
0	88.27±6.40	88.27±7.24	91.46±8.61	91.46±8.61	92.07±10.23	92.07±10.23
10	94.63±11.42	97.91±8.24	95.06±9.23	98.49±8.34	97.07±12.18	106.21±9.05
15	100.31±9.47	105.42±9.45	103.43±9.42	106.09±8.41	104.98±12.28	109.26±8.28
20	103.26±7.68	108.34±9.26	107.19±9.13	109.17±12.16	110.14±8.28	117.27±12.24
25	107.61±8.53	110.58±9.36	109.97±10.24	115.49±9.25	116.59±9.91	129.07±9.31
30	109.64±10.64	116.76±10.48	114.18±11.18	124.96±9.27	121.46±10.49	132.16±10.13
35	118.06±9.11	–	122.18±8.37	–	129.53±11.16	–
40	125.12±10.18	–	130.89±11.47	–	135.09±8.18	–
50	133.5±10.18	–	136.49±10.19	–	140.15±12.37	–

Values in the table are mean (±SD)

Table 5 %V_{O2max} of scaffolders while carrying load in head and shoulder mode

Load (kg)	21-30 years		31-40 years		≥41 years	
	Head mode	Shoulder mode	Head mode	Shoulder mode	Head mode	Shoulder mode
0	20.81	20.81	21.37	21.37	22.17	22.17
10	23.51	24.92	24.06	26.17	25.64	27.04
15	24.72	28.03	26.37	28.18	26.91	31.57
20	29.03	31.49	31.05	34.63	31.48	35.26
25	30.28	33.25	32.19	38.48	33.91	39.08
30	34.91	35.18	34.75	41.07	36.59	43.73
35	37.27	–	38.19	–	41.07	–
40	39.18	–	41.54	–	42.07	–
50	40.57	–	43.48	–	44.74	–

The literature study [35-37] on acceptable loads indicated that HR of ≤110 bpm should be preferable and an oxygen consumption of 30-35% V_{O2max} should be preferred. Tables 4 and 5 indicate that while carrying a load of 30 kg in the head mode by scaffolders aged between 21-30 years, HR and the oxygen intake were below as reported by [35-37]. However, while carrying a load of 35 kg, HR and the oxygen intake were beyond the specified level.

The HR and the oxygen intake for the scaffolders aged between 31-40 years were lower than the level reported by [35-37] while carrying a load of up to 25 kg. However, while carrying loads above 25 kg, the oxygen consumption was less but HR was over as reported by [35-37]. As the scaffolders aged ≥41 years carried variable loads up to 20 kg on head mode, both the HR and oxygen intake were lower than the level reported by [35-37]. However, while carrying load of 25 kg, although the intake of oxygen was lower than 35% V_{O2max}, the HR was over the 110 bpm. Nevertheless, for carrying the loads above 25 kg, both HR and the intake of oxygen were over as reported by [35-37].

In the shoulder mode, both the HR and the oxygen intake were lower than the level reported by [35-37] for scaffolders aged 21-30 years and 31-40 years carrying loads up to 20 kg as well as aged ≥41 years carrying loads up to 15 kg,.

From physiological perspective, the recommended load is up to 30 kg, 25 kg, and 20 kg at a walking speed of 2.5 km/h for scaffolders aged 21-30 years, 31-40 years, and ≥41 years, respectively. In fact, the real walking speed in the field for the selected age groups was 3.9 km/h, 3.7 km/h, and 3.3 km/h, respectively. Accordingly, the advisable loads should be less than 30 kg, 25 kg, and 20 kg depending on the field conditions for scaffolders aged 21-30 years, 31-40 years, and ≥41 years, respectively. The results of the study were also supported by [26, 38].

3.6 EMG Results

Figures 8 and 9 illustrate that the average EMG values (RMS volts) of the neck(r), trapezoid(r) and errector spinae(r) muscles while carrying different loads by the scaffolders (N=10) of average age 29.7 years, average weight 59.2 kg, and average height 160.4 cm for 20 mins continuously in the head and shoulder mode.

During the load carrying activity in the head mode, the trapezoid(r) muscle ($p<0.02$) showed the maximum activity followed by the neck(r) muscle and the erector spinae(r). EMG values increased gradually with the increase in load, except in the case of erector spinae(r) where the EMG values dropped. But in case of shoulder mode, only trapezoid(r) muscle (p<0.0.5) showed the gradual increase in EMG values with the increase in load. In case of trapezoid(r) muscle, significant differences were observed between no load and other loads ($p<0.05$). This was also confirmed by subjective evaluation while identifying muscular pain. The EMG results were also supported by Cook [15]. It can also be observed from the Figures 8 and 9 that the EMG values (RMS volts) of different muscles showed high increase after a load of 25 kg in head mode and 20 kg in shoulder mode. Therefore, the results of the EMG suggested that the maximum carrying load should be around 25 kg for head mode and 20 kg for shoulder mode to avoid the muscle fatigue and MSDs.

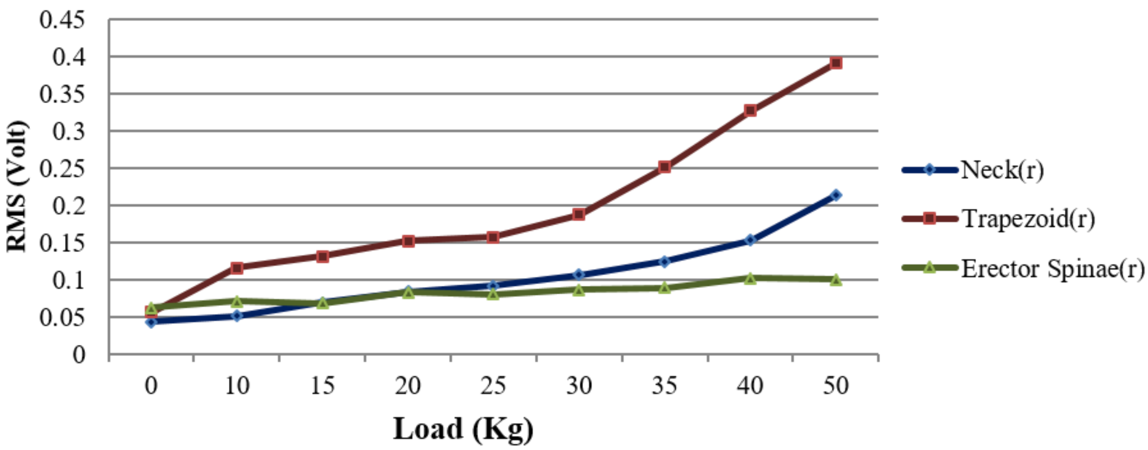

Figure 8 EMG Activity (RMS-volts) of selected muscles during load carrying on Head

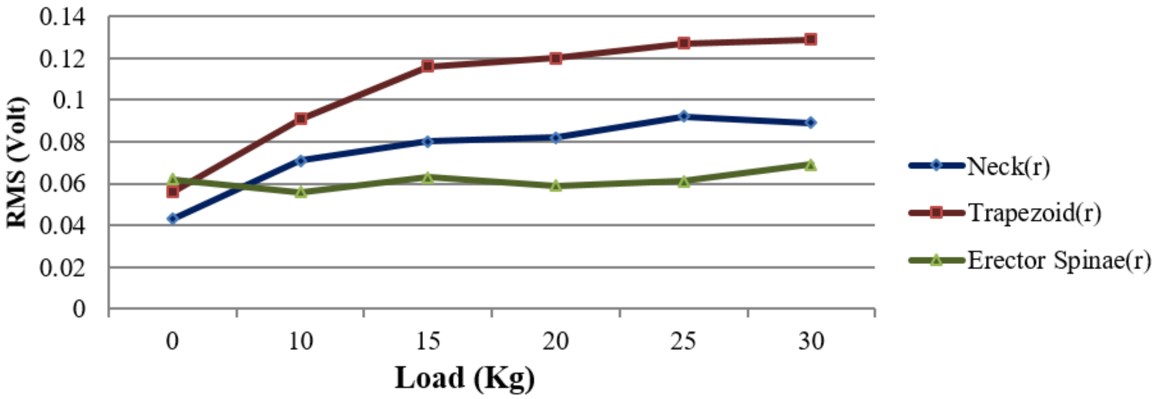

Figure 9 EMG activity (RMS-volts) of selected muscles during load carrying on shoulder

3.7 Psycho-physiological evaluation

The psycho-physiological assessment of the scaffolders of age groups 21-30 years, 31-40 years, and ≥41 years involved in continuous load carrying activities were chosen randomly for the study. At the end of the load carrying activity in head mode, a large number of scaffolders aged 21-30 years selected 28 kg, 31-40 years selected 23 kg, and ≥41years selected 20 kg. While in shoulder mode, scaffolders aged 21-30 years selected ≤21 kg, 31-40 years selected ≤20 kg, and ≥41 years selected <15 kg. The results of the psycho-physiological were also supported by the findings of other studies [20, 26, 39].

4. Conclusion

The results of present investigation confirmed that the scaffolders were working under high physiological stress, which made it imperative to fix a maximum load limit that they could carry for 8 hrs and it would also provide a safe working environment for scaffolders. Therefore, on the basis of psycho-physiological and physiological evaluation, the EMG analysis, the existing irregular terrain, physiological strain index, work-pause schedule, HR variability, walking speed and the summer environmental heat stress, the study concludes that

I. The maximal carrying load for scaffolders in head mode on a plain surface should not exceed 28 kg for 21-30 years, 23 kg for 31-40 years, and 20 kg for ≥41 years.

II. In shoulder mode, the maximal carrying load should not exceed 21 kg for 21-30 years, 20 kg for 31-40 years, and 15 kg for ≥41 years

The present investigation suggested that if the findings of this research work is introduced for workers of the unorganized sectors, the chances of workers being stuck with accidents (MSDs) will be significantly lowered and the production rate will be enhanced because healthy workers can be more efficient than those in poor health.

5. References

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