Short Report

Physiological workload assessment with the help of heart rate and perceived exertion rating on handcart pullers of wholesale trade markets of Delhi

AMOL, SANGEETA PANDIT

ABSTRACT

Background. Handling a heavy load on a handcart is common in the wholesale and retail trade markets in India and many parts of the globe. These carts transport goods between major markets, warehouses and transporters. We assessed the physiological workload among handcart pullers in terms of cardiovascular load (CVL), energy expenditure (EE), heart rate (HR), physiological cost of work and subjective rating of perceived exertion.

Methods. Physiological workload was assessed with the help of HR during resting, working (15 minutes) and recovery state with a smart wearable device to extrapolate percentage of CVL, EE and physiological cost of work among handcart pullers. Subjective assessment of exertion was measured with the Borg 5-point rating scale among 35 cart pullers. Data were analysed using Microsoft Excel version 2010.

Results. It was found that in handcart-pulling activity, EE was 11.706 kJ/minute, average working HR was 128 beats/minute and physiological cost of work was 89.09 beats/minute with no loads on handcart. This signifies that the activity falls under heavy physiological workload. The average percentage of CVL was found to be 50.5%, which falls under acceptable category for persons with a healthy cardiovascular system. Thirty-one (88.6%) of the participants reported the activity to be moderately heavy, whereas 4 (11.4%) participants mentioned it to be light.

Conclusions. Handcart-pulling operation in this study without load on cart was found to be a heavy physiological workload. In real-time situations, the load, road conditions, long duration and traffic congestion is likely to result in a higher range of physiological workload on cart pullers.

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INTRODUCTION

Most efficient means of transporting heavy loads, in terms of minimal energy cost to the human body, have been the subject of research for many years. Manual material handling (MMH) is an unaided human act of lifting, lowering, pushing, pulling, carrying, holding and releasing an object. In India, due to ease of availability of labour force and unemployment problem, MMH constitutes a major part of material-handling activity in different industrial and transportation sectors. One such activity is handcart pulling. These two-wheeled handcarts are relatively unsteady and loads are transported by balancing them in the horizontal plane. Transporting commodities using these carts in metropolitan cities is a major source of earning for a large section of the labour force that comes from poor families of small towns and villages of India. These handcarts are commonly used in wholesale and retail trade markets across India and many parts of the globe, especially Southeast Asian countries. Hand-pulled carts are the backbone of non-motorized transportation of goods between major markets, warehouses and transporter.

We did this study in a wholesale trade market of Delhi where thousands of tons of major commodities are transported by handcarts (Fig. 1); 12 860 tonnes of goods per day are transported, which is 34.3% of the total goods transported.[1] On average, the loads carried on the handcart vary from 200 to 1000 kg. Loads above 500 kg are supported by assistant pullers. The usual distance travelled ranges from 200 m to 4 km, though sometimes the distance may be 25 km or more. These handcarts fit into the narrow roads of wholesale markets, they are non-motorized, do not cause pollution and are environment-friendly.[2] Handcarts are an economical mode of transportation compared to their motorized counterparts.

Casual observation suggests that this group of workers undergo considerable stress due to MMH. High physical stress can lead to work-related injuries and health issues resulting in early retirement and financial burden on the family and society.[3] A sizeable number of the labour workforce is involved in the occupation of handcart pulling, but so far, it has not received the attention it deserves.

Some physiological workload assessments have been done on MMH of handcart pullers, rickshaw pullers (mainly used for carrying passengers) and luggage or load transporters. In one of the studies, the cardiovascular load (CVL) was found to be very high on van-rickshaw pullers of West Bengal during the summer months.[4] In another study, evaluation of one-hand luggage-pulling task, it was found that wheel diameter of the cart and subject height were associated with physical stresses of luggage users.[5] In another study, it was found that large wheel size and high tyre pressure were associated with low energy cost among pullers.[6] Energy expenditure (EE) of hand-pulled rickshaw was observed to be 'moderately heavy' to 'heavy' even without any load on the rickshaw.[7] In another study, EE in MMH in warehouse operator was found to exceed the energy consumption limit.[8] A study on cycle rickshaw pullers found that EE and cardiac cost of work were heavy to very heavy.[9] Similarly, another study on hand-pulled rickshaw pullers found that energy cost varies with loads rather than the speed of pulling the rickshaw.[10]

Studies have used EE to evaluate workload[7–10] with the help

FIG 1. Loaded hand-pulled cart

of oxygen consumption in MMH, but this approach is difficult in natural settings such as wholesale market places. Hence, we measured the heart rate (HR) to evaluate physiological workload among handcart pullers. We assessed the physiological workload of handcart pullers in terms of CVL, HR, EE and subjective rating of perceived exertion (RPE) to execute the heavy MMH task. Assessments of physiological workload could help suggest ergonomic changes in the handcart design.

METHODS

A descriptive, cross-sectional study was done on handcart pullers of wholesale and trade markets of Khari Baoli, Azad Market, Naya Bazar, Pahar Ganj and Karol Bagh areas of Delhi. Thirty-five healthy handcart pullers were selected using non-probability convenience sampling from 1 to 15 June 2020. Data collection for this study was done after the study was approved by the Institutional Ethics Committee on 26 May 2020. Written and oral consent was taken from each participant, and confidentiality of the data was maintained.

The data were collected during the early morning when the markets were closed and there was no traffic. The cart pullers were asked to perform the experiment on a 100 m straight road without inclination and assistant cart pullers. Due to the busy work schedule of the handcart pullers, they could not spend time for an interview and the data collection process. Hence, a smart wearable device technique was used for data collection to assess the workload.[11,12] Smartwatch Samsung galaxy active two model was used to measure the HR of the subjects by the photoplethysmography method.[13] The HR was read directly from the dial of the smart watch by the investigator. HR is a reliable parameter to infer about the physiological workload. The average HR was recorded in three conditions; resting, working and recovery conditions. The reading of the resting HR was taken before they started pulling the cart (10 minutes before the task) after taking a 20 minutes rest under a shed. Readings of three resting heart rates per minute were taken at a gap of 1 minute and the average was taken. The working HR during pulling the cart represents an average of 15 minute HR measured at the end of each minute for pulling the dry weight of the cart, which weighs 180 kg and is 9.5 feet long. Finally, recovery heart rate was measured after 10 minutes of rest following the cart-pulling activity. Again three HR readings were taken at 1 minute gap and averaged. The speed limit of cart pulling was maintained at 5 km/hour by the investigator following the cart puller by two-wheelers alongside the handcart. The following formulae were used to calculate the physiological workload of the cart pullers.

EE was estimated from the average HR calculated by using the following formula:[14]

$$EE\ (kJ/min)=0.159\times\text{average HR (beats/minute) during work}-8.72 \quad (1)$$

The physical workload of the cart pullers was analysed from the HR and percentage of cardiovascular workload (CVL) was calculated according to the following equation:[15]

$$CVL=([HR\ working-HR\ resting]/[HR\ max-HR\ rest])\times 100 \quad (2)$$

where: HR working is HR at work, in beats/minute, HR resting is HR at rest, in beats/minute; HR max=208–0.7×age

Total cardiac cost of work (TCCW) is a sum of the cardiac cost of work and cardiac cost of recovery; measured by applying the following formula:

$$TCCW=CCW+CCR \quad (3)$$

where: cardiac cost of work (CCW)=AHR×duration of work (in this case 15 minutes)

AHR=(average HR working–average HR resting)

CCR=(average recovery HR–average HR resting)×duration of recovery

$$\text{Physiological cost of work (PCW)}=TCCW/\text{duration of work} \quad (4)$$

To normalize the values of HR to check the influence of personal, psychological and environmental factors, an increase ratio of HR (IRHR) was performed. The following formula was used to calculate IRHR.[16,17]

$$IRHR=HR\ working/HR\ resting \quad (5)$$

For comparison with the obtained values the recommended category or classification used are provided in Tables I to III.

Considering the fact that the subjects selected for this study were uneducated and their inability to discriminate the finer details of the Borg 10-point scale, a modified 5-point scale was constructed and used to measure RPE[18,19] of cart-pulling activity. The rating scale administered to all the subjects was:

1. Very light
2. Light
3. Moderate heavy
4. Heavy
5. Very heavy

Only one handcart puller was interviewed at a time to avoid loss of productive time.

The inclusion criteria were participants who willingly participated in this study, had not undergone any operation in the past 3 months of the study and were physically fit. Physically challenged cart pullers were not included.

TABLE I. Recommended workload levels

Physiological workload	Physiological variable		
	Heart rate[14] (beats/minute)	Energy expenditure[14] (kJ/minute)	Physiological cost of work[21] (beats/minute)
Very light	< 90	< 5.0	–
Light	91–105	5.1–7.5	0–36
Moderately heavy	106–120	7.6–10.0	36–78
Heavy	121–135	10.1–12.5	78–114
Very heavy	135–150	12.6–15.0	114–150
Extremely heavy	> 150	>15.0	>150

Statistical analysis was done using Microsoft Excel version 2010.

RESULTS

The subjects were between 24 and 41 years of age (mean [SD] 30.8 [4.45] years) with a mean (SD) body weight of 60 (8.86) kg and a mean (SD) height of 158.84 (8.46) cm. The obtained HR, EE and PCW values on pulling the dry weight of the cart without load were compared with the already established physiological workload classification data chart (Table I). The average working HR while performing the activity was 128.47 beats/minute. EE was found to be 11.706 kJ/minute and PCW was 89.09 beats/minute. The above values when compared with the established physiological workload classification data chart (Table I) fall under heavy physiological workload.

Similarly, the obtained average CVL (%) value for 15 minutes work was 50.51% (range 44.05% to 57.28%). The average percentage CVL value indicates that the workload is acceptable only for persons with a healthy cardiovascular system (Table II). Even though CVL (%) is under the acceptable limit for a healthy person, the IRHR value that is helpful to normalize HR values is 1.87, which is in the very heavy category of workload (Table III).

The perceived exertion rating of handcart-pulling activity reported by the 35 was as follows: 31 (88.6%) felt the work was moderately heavy, whereas 4 (11.4%) felt it was light workload.

DISCUSSION

Our study was conducted in a situation close to the real work scenario. This helps to obtain the physiological reaction of the workers from HR, a parameter of physical strain in response to workplace stressors. HR was used as the principal parameter because it provides an integrated response to EE, CVL and PCW.[20] IRHR is done to avoid a subjective HR value which is influenced by other factors such as personal, psychological and environmental conditions. IRHR helps to normalize HR values to obtain an objective HR.[16] The obtained IRHR value in our study was 1.87, which indicates that without any influence of other factors the cart-pulling activity falls under the very heavy category of workload (Table III). Similarly, obtained average working HR was 128.47 beats/minute indicating that cart-pulling activity is heavy physiological workload (Table I). Another study on men construction workers termed HR that exceeds 106–110 beats/minute to be critical activity.[16] CVL (%), which takes into consideration both resting and maximum HR, was 50.51% and gives the best expression of circulatory strain (Table II). In our study, there was no load on the cart, and the experiment was done on a level road without inclinations. Hence, the obtained value of % CVL is within acceptable limit for persons with a healthy cardiovascular system, but in a real-time situation, the cart pullers need to pull large loads suggesting that % CVL would be much higher compared to the obtained value.[20] Also, the experiment was conducted in the early morning hours when the markets were closed and there was no traffic congestion on the road. Even though the % CVL is towards the lower limit of the classification (Table II), while pulling a loaded cart, the CVL may go above this range and even into the unacceptable range. The PCW in our study was 89.09 beats per minute which is considered as heavy physiological workload (Table I). PCW also takes into consideration both resting and maximum HR along with the duration of executing the work.[21] In our study, EE without a load on the cart was 11.706 kJ/minute, which falls under heavy physiological workload (Table I).[7] Our findings are similar to those of the study on handcart pullers of Kolkata,[7] but the design of the cart is different from that used in our study. In a real-time situation, with a change in load on the cart, maximum HR values will change, which will have a direct influence on the classification of the physiological workload of cart-pulling activity.

While performing an activity, an individual can complain of tiredness or fatigue, which is a subjective feeling that provides reliable information for assessment of the workload.[19] In case of RPE, 11.4% of the participants rated the cart-pulling activity to be light physiological workload, whereas 88.6% of them reported that the work comes under moderately heavy workload. This may be because the handcart pullers were used to carrying more loads in an actual situation. As the experiment was conducted without loads on the cart, the cart pullers possibly felt the workload to be

TABLE II. Workload classification based on percentage cardiovascular load (CVL)

Classification	CVL (%)
	Short-lasting activities[18]
Very low	<25
Relatively low	26–35
Medium	36–50
Acceptable only for persons with a healthy cardiovascular system	51–65
Conditionally acceptable	66–80
Not acceptable	>80

TABLE III. Workload category based on increase ratio of heart rate (IRHR)

Category	IRHR value[16]
Light	1.00<IRHR<1.25
Average	1.25<IRHR<1.5
Heavy	1.5<IRHR<1.75
Very heavy	1.75<IRHR<2.00
Extremely heavy	2.00<IRHR

less strenuous. Poor labour force in the unorganized sectors due to the lack of job security adjust themselves to work in high workload situations which over time becomes a habit.

Several studies on occupational health found a positive correlation between physiological strain and subjective estimation of fatigue. This led them to conclude that subjective assessment of perceived exertion is a simple and good tool for determining fatigue criteria.[22–25] One of the occupational health reseachers did an extensive study and proposed a rating scale based on perceived exertion and found it correlated with physiological responses such as EE and HR, which are now established as a practical method for determining occupational workload.[19] An important insight which surfaced during assessment of perceived exertion rating is that small metal wheel of the handcart with a diameter of 39 cm increases the frictional forces on the road, increasing exertion rate of pulling the handcart.[7]

The findings of our study can be used for various other transportation sectors in India, where handcart is one of the major non-motorized modes of transportation of goods such as in ports, and domestic and international airport cargo terminal. A handcart is used extensively in the Indian Railways for transporting freights from passenger and goods train to different railway platforms and godowns. In wholesale and trade markets, the handcart pullers with huge loads on the cart need to work in consonance with traffic, congestion and crowded market place, transportation of goods against uphill and downhill conditions.

The limitations of our study: to avoid crowded places due to Covid-19 in Delhi, the study could not be done in a real-time situation with loads. In the actual situation, cart pullers carry heavy loads through congested heavy traffic conditions repeatedly for a couple of times throughout the day. Hence, the physiological workload will be much higher compared to the obtained results. Moreover, it was observed that some of the carts have metal wheels with rubber padding and also ball bearing between axel and wheel, but how this wheel design can reduce workload of the cart pullers needs to be studied from the engineering design aspect.

Ergonomic design intervention in the design of the handcart to reduce physiological workload and frictional force due to metal wheel is the need of the hour. This will, directly and indirectly, impact a vast workforce involved with handcart-pulling occupations.

Conclusions

Our study has shown that the use of HR as a strain indicator is especially useful in the assessment of workload burden in terms of EE, CVL and PCW. Physiological workload refers to the amount of effort a worker put while doing a certain task. Work with high physiological demand, represented from obtained result classifies cart pulling under heavy physiological workload. Our study was conducted without any loads on the cart, but in a real-time situation, other added factors such as load, incline of the road, traffic congestion, etc. would bring about a much higher physiological workload compared to the results in our study. RPE scale is considered a reliable parameter for predicting workload at high dynamic work intensities. However, in our study, estimation of physical effort with the Borg scale performed was different from physiological workload assessment with the help of HR. In the experimental setup unlike real condition, the subjects rated the tasks slightly less strenuous. Thus, evaluating RPE for real-time situation seems to be more appropriate.

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Conflicts of interest. None declared

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