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Assessment of Physiological Workload Related to Selected Manual Material Handling Tasks

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ABSTRACT For more than a decade, farming has been rated one of the most hazardous occupations in the developing countries. Many risk factors associated with the development of musculoskeletal disorders are common place in agricultural tasks. Occupational risk factors include static positioning, forward bending, heavy lifting and carrying, kneeling, and vibration. The present study was conducted in villages of Mawali tehsil of Udaipur on a sample of 30 agricultural workers (15 male and 15 female) engaged in agricultural tasks from last 10 years. Heart rate data were collected for determining physiological workload before and after intervention of self -designed technology namely Single Wheel Hand Truck (SWHT) and Double Wheel Hand Truck (DWHT)] ._ It was concluded that Double Wheel Hand Truck and Single Wheel Hand Truck were better option for carrying loads than the traditional method of carrying load and also that DWHT was better than SWHT.

INTRODUCTION

Agriculture is an occupation framed within the context of family and community. The farm family is the central entity in agricultural production involving every member be it children, women or the elderly. It is carried out in a rural environment and there is no clear-cut distinction between working and living conditions. The symbiotic relationship between home and work allows all family members to be exposed to occupational hazards of the farm operations. Thus, agricultural worker is subject to the health hazards not only of the rural environment but also of those inherent in the work processes.

For more than a decade, farming has been rated one of the most hazardous occupations in the developing countries. A considerable number of adverse health conditions, including musculoskeletal disorders, are linked to agricultural work. Many risk factors associated with the development of musculoskeletal disorders are commonplace in agricultural tasks.

Occupational risk factors include static positioning, forward bending, heavy lifting and carrying, kneeling, and vibration. Unfortunately, there has been limited application of research related to ergonomics and musculoskeletal disorders, although farmers frequently report signs and symptoms of musculoskeletal problems. Women in rural areas spend most of their time meeting the basic needs of the family, such as fetching water and firewood, preparation of food and caring for dependants. The responsibility of obtaining fresh water for drinking, cooking, cleanliness, and hygiene, often from long distances in heavy containers, is almost exclusively that of women and girls. In many countries trips to collect firewood and water are predominantly made by women (and children). In some countries, women providing food for the family through subsistence farming are often allocated the poorest fields farthest from the village. This increases their daily travel distance (Bryceson and Howe 1995). Small-scale studies in Asia and Africa indicate that women and girls spend an average of 5-17 hours per week in collecting and carrying water (UN 1991). Carasco (1994), Hatcher Roberts and Law (1994) stated that many of the traditional responsibilities of women in the developing world are load-associated: women often carry, lift, and transport heavy loads in their daily activities. Butler et al. (1997) reported that when the trip to a water source is facilitated by other means of transport (such as a bicycle, donkey, wheelbarrow, or oxcart), some men may become involved.

Rural communities often lack access to appropriate technologies which may result in various health hazards. Farm workers often view pain as a normal part of work and seek care when the condition becomes severe or disabling. This same issue carries over to preventive measures designed to reduce the incidence of musculoskeletal injuries or other hazardous work exposures. Frequently, workers do not understand the association of a problem with its source because of cultural misunderstandings.

Manual Material Handling (MMH) is defined as the unaided moving of objects, often combined with twisting and awkward postures, and contributing to musculoskeletal disorders. Traumatic occurrences (slips, trips, falls, and blows to the body) cause other bodily injuries, pains, and disabilities. Typically, not one specific occurrence but rather the awkward body positions, repetition, force, and duration associated with movement lead to back, neck, and other problems like Cumulative Trauma Disorders (Anonymous 2007)

According to Dufault (1998), often head loading is the only means of moving goods around the farm or village. It is an inefficient and slow means of transport, often causing spinal injuries and other health hazards. The lifting and carrying of loads in subsistence and agriculture on small landholding are unavoidable. With the prevalent levels of poverty in rural areas and the lack of infrastructure, many people are carrying loads of 30 kg or more on their heads, shoulders and backs for long distances. In developing countries the lack of automation in agricultural fields necessitates the increased prevalence of manual materials handling tasks.

There are various health effects due to carrying heavy loads. Water is carried on the head, the back, the shoulder, or the hip, depending on the region of the world, and each method may create health problems for women. Women who carry water on their back often walk in a stooped position. Asymmetric shoulder carrying may cause the body to develop more loads on one side. Hip damage can result from carrying water on the hip (APDC 1990), and the carrying of water on the back using a head strap may lead to severe headaches. The Asian and Pacific Development Centre (APDC) also pointed out that women are exposed to skeletal problems, which could lead to deformity and disability. Carrying heavy loads over long distances is physically demanding and exhausting work. In addition to fatigue, heavy weights can cause an increased incidence of back strains, lower-back pain, fractures, chronic and debilitating back and leg problems, damage to the knees, and other physical damage (ILO 1989 and Haile 1995).

According to Nag (1995), in Viet Nam heavy physical work is common and loads carried on the head were found to have a detrimental effect on the vertebrae of workers (especially in the neck region). Carrying heavy loads, such as large containers of water, can also lead to a prolapsed uterus (Labour Resource Centre 1995) and is associated with menstrual disorders, miscarriage, and stillbirth (NCSEW 1998).

The biomechanical stresses of material handling have been studied in sophisticated laboratory conditions but one area which lacks research backup is assessment of physiological workload in MMH tasks particularly carrying, lifting etc. Manual vehicles, such as carts, hand trucks, wheelbarrows, etc., have been of great advantage to the transportation of materials due to the presence of wheels. Over decades, many studies have shown that the use of manual vehicles is less stressful and more efficient than their non use in manual material handlings (Banerjee et al. 1959; Haisman et al. 1972; Jager et al. 1984 and Schibye et al. 2001).Thus, in the present investigation the physiological cost of work was assessed to test the effectiveness of the designed MMH technology (hand truck).

METHODOLOGY

The present study was conducted in five villages of Mawali tehsil of Udaipur District. Farming is the main occupation of the people, maize and wheat are the main crops grown and dairy is the subsidiary occupation of 60 percentof the population.

Heart Rate Data Collection for Determining Physiological Workload Before and After Intervention of Self -designed Technology: The heart rate data was collected from 30 workers (15 male and 15 female agricultural workers) before and after self designed technology intervention. In order to collect data the subjects were asked to lift vegetable loads of various capacities (5kg to 20kg) in traditional method involving head loading and by using self -designed Single Wheel Hand Truck (SWHT) and Double Wheel Hand Truck (DWHT) and walk while carrying load to a distance of 400 m.

Recording Heart Rate: For the purpose of obtaining a measure of cardiac strain, Polar Heart Rate monitor was used. The Polar Coded Transmitter, which measures the heart's electrical activity, was fitted around the subject's chest with an elastic strap at the level of the inferior border of the pectoral muscles and in line with the left ventricle situated slightly to the left of the mid-centre of the chest. A receiver worn as a wrist-watch recorded the heart rate responses at 15-second intervals during the field testing sessions.

The agricultural workers who were not familiar with such technology, anticipation could have distorted resting heart rates. A habituation period was therefore arranged during which the experimenter explained the technology to the workers, fitted them with the heart rate monitors. After preparing the subject for the experiment the subject was asked to sit in shade in a relaxed position for 10 minutes. This was followed by taking resting heart rate for 5 minutes. Then the subject was asked to perform the activity of transporting various loads of vegetables to a distance of 400m. During performance of activity working heart rate was taken which varied from 15-20 minutes in covering standard distance of 400m. Immediately after the termination of the activity the subjects was given rest and recovery heart rate was recorded for 5 minute duration. Heart rate (HR) for every minute was recorded.

In order to collect heart rate data the subjects were asked to lift vegetable loads of various capacities (5kg to 20kg) in traditional method involving head loading and walk while carrying load to a distance of 400m.

During intervention with hand truck they were asked to carry loads of various capacities (5kg to 20kg) and fill bag of SWHT and basket of DWHT and then push the hand trucks to a distance of 400 m.

Physiological Cost of Work: Heart rate data was used to calculate-

$$\text{Physiological Cost of Work} = \frac{\text{Total Cardiac Cost of Work (TCCW)}}{\text{Total time of activities}}$$

TCCW = Cardiac Cost of Work (CCW) + Cardiac Cost of Recovery (CCR)
CCW = Average Heart Rate (AHR) X Duration
AHR = Average Working Heart Rate - Average Resting Heart Rate
CCR = Average Recovery Heart Rate - Average Resting Heart Rate X Duration

Rating of Perceived Exertion (RPE) Scale for Assessing Perceived Discomfort: Pain is the indicator of discomfort. The perceived discomfort was recorded in terms of pain felt in various parts of the body by the subjects while performing the activity. The RPE scale developed by Varghese et al. (1994) was used to subjectively assess the exertion perceived.

RPE scale	*Psycho-physical workload*
1	Very light
2	Light
3	Moderately heavy
4	Heavy
5	Very heavy

RESULTS AND DISCUSSION

Physiological Workload

The use of heart rate monitors is a popular means to determine the degree of physical exertion. Vuori (1998) found that the constant fluctuations in heart rates occur due to changes in breathing rate, blood pressure, hormones, various actions of the sympathetic and parasympathetic nervous systems and emotional states, as well as working postures, environmental influences and health status, complicating the analysis of heart rate responses due to a specific activity alone. Kapitaniak (2001) explained that despite the great variations in heart rates due to intra-individual differences, the majority of people display average resting heart rates between 60 and 90 beats per minute (bmin^{-1}).

An overview of Table 1 depicts that average working heart rate was higher when load of 5 kg (male 136.14 bmin^{-1} and female 138.18 bmin^{-1}), 10 kg (male 137.16 bmin^{-1} and female 138.45 bmin^{-1}), 15 kg (male 137.93 bmin^{-1} and female 138.50 bmin^{-1}) and 20 kg (male 138.43 bmin^{-1} and female 140.38 bmin^{-1}) was carried by traditional method using head mode by both the genders in comparison to when newly designed technologies i.e. hand trucks were used. This fact is confirmed by data which shows that there was maximum change in heart rate values of work over rest depicted by HR when traditional method of carrying load of various weights was used as compared to when SWHT and DWHT were used by both the genders. The attraction of the implementation of carts is that a well-designed cart can be used to move heavy loads with forces that are acceptable to the majority of the workforce, thereby reducing the demands on the musculoskeletal system of the operator (Ciriello 2004).

The AWHR of both male and female respondents was higher when SWHT was used for carrying 5kg (male 128.58 bmin^{-1} and female 128.72 bmin^{-1}), 10 kg (male 128.85 bmin^{-1} and female 129.96 bmin^{-1}), 15 kg (male 131.28 bmin^{-1} and female 131.28 bmin^{-1}) and 20 kg (male 134.01 bmin^{-1} and female 134.96 bmin^{-1}) in comparison to when DWHT was used. The underlying reason might be SWHT required more effort in balancing load while DWHT had two wheels which required less human effort to balance the load.

Despite the obvious attractions of manual materials handling devices to reduce the risk of the development of musculoskeletal problems, and the now widespread use of trolleys in all types of industrial organizations. Mack et al. (1995) argued that little attention has been given to the ergonomics aspects of their design. The same risks that apply to the assessment of lifting tasks still remain when using handling devices, as they still require the operator to exert force. Mack et al. (1995) caution that the use of mechanical aids without the appropriate attention to ergonomic factors may result in their causing more problems then they were intended to solve.

The data also show that the AWHR of male respondents was always lower than female respondents when they carried 5 kg, 10 kg, 15 kg and 20 kg load by any mode whether it be traditional method, SWHT and DWHT. On an average working heart rate was higher when the load was carried using traditional method of head loading than using improved technology for material handling, that is, SWHT and DWHT. It is clear from the ÄHR data in the table that both male and female respondents found DWHT a better mode of carrying 5 kg, (male 122.05 bmin^{-1} and female 125.07 bmin^{-1}), 10 kg (male 128.73 bmin^{-1} and female 128.90 bmin^{-1}), 15 kg (male 129.80 bmin^{-1} and female 131.33 bmin^{-1}) and 20 kg (male 132.16 bmin^{-1} and female 133.17 bmin^{-1}).

Straker et al. (1996) found the physical limits for pushing and pulling to be more than double the limits for lifting, lowering and carrying, as well as being subjectively rated as being less strenuous than lifting. The classification of psycho-physical workload (Varghese et al. 1994) of the activity based on Rating of Perceived Exertion (RPE) Scale in the Table 1 showed that the physiological workload was 'Light' when the traditional method of carrying load on head was adopted by male respondents to carry load of 5kg and 10 kg while the female respondents perceived 'Light' physiological workload when they carried 5 kg of load. The male and female respondents found the load carrying activity 'Moderately Heavy' when they carried 15kg and 10 kg load respectively. The psycho-physical workload fell in the category of 'Heavy' when they carried load of 20 kg using traditional method whereas female respondents experienced 'Heavy' physiological workload when they carried 15kg of load. The male and female respondents found that when they carried load of 5kg, 10 kg and 15 kg using SWHT they felt it 'Light'. The male and female respondents perceived 20 kg of load as 'Light' and 'Moderately heavy' respectively when they carried it using SWHT. Table 1 clearly depicts that when both the male and female respondents used improved technology DWHT for carrying load ranging from 5 to 20 kg they

Table 1: Heart Rate data of respondents when carrying load of various weights, using traditional method, single and double wheel hand truck (N=30)

Load	*Respondent*	*ARHR* (bmin^{-1})*			*ÄHR^{+} (bmin^{-1})*			*AWHR^ (bmin^{-1})*			*Average rating of perceived exertion*		
		TM	*SWHT*	*DWHT*	*TM*	*SWHT*	*DWHT*	*TM*	*SWHT*	*DWHT*	*TM*	*SWHT*	*DWHT*
5Kg	Male (n=15)	77.52	77.57	77.73	58.62	51.00	44.31	136.14	128.58	122.05	L	L	L
	Female (n=15)	78.09	77.87	77.28	60.09	50.86	47.79	138.18	128.72	125.07	L	L	L
10Kg	Male (n=15)	77.68	77.55	76.77	59.48	51.31	51.96	137.16	128.85	128.73	L	L	L
	Female (n=15)	76.64	77.39	76.96	61.81	52.57	51.94	138.45	129.96	128.90	MH	L	L
15Kg	Male (n=15)	76.79	76.80	77.52	61.14	54.48	52.28	137.93	131.28	129.80	MH	L	L
	Female (n=15)	77.60	77.95	78.37	60.90	53.39	53.42	138.50	131.33	131.79	H	L	L
20Kg	Male (n=15)	77.36	77.29	76.69	61.07	54.87	57.32	138.43	132.16	134.81	H	L	L
	Female (n=15)	77.92	77.52	71.87	62.46	55.65	57.10	140.38	133.17	134.96	H	MH	L

TM- Traditional Method
SWHT- Single Wheel Hand Truck
DWHT- Double Wheel Hand Truck
*ARHR=Average Resting Heart Rate
+ÄHR =Average Heart Rate
^AWHR=Average Working Heart Rate

Table 2: Total cardiac cost of work and physiological cost of work of respondents carrying loads of various capacity using traditional method, single and double wheel hand truck (N=30)

Load	Respondent	AWHR (bmin-1)			TCCW (beats)			PCW (beats)		
		TM	SWHT	DWHT	TM	SWHT	DWHT	TM	SWHT	DWHT
5 Kg	Male (n=15)	136.14	128.58	122.05	547.79	426.95	360.47	29.97	24.82	21.72
	Female (n=15)	138.18	128.72	125.07	642.44	541.06	500.93	32.67	27.99	26.18
10Kg	Male (n=15)	137.16	128.85	128.73	607.52	443.80	431.01	31.64	25.22	24.58
	Female (n=15)	138.45	129.96	128.90	664.05	633.80	561.37	33.77	30.37	28.54
15Kg	Male (n=15)	137.93	131.28	129.80	628.04	527.64	494.05	32.48	28.54	26.95
	Female (n=15)	138.50	131.79	131.33	739.97	621.32	620.12	35.01	30.36	30.01
20Kg	Male (n=15)	138.43	134.81	132.16	734.32	568.64	565.41	34.86	29.93	29.76
	Female (n=15)	140.38	134.96	133.17	834.84	666.84	661.83	37.38	32.16	31.92

perceived 'Light' psycho-physical workload. From this it is clear that DWHT and SWHT are better option for carrying loads than the traditional method of carrying load and also that DWHT was better than SWHT.

Chaffin et al. (2001) identified two types of hazards relating to pushing and pulling which are likely to lead to injury or musculoskeletal complaints. Firstly, if there is a mismatch between the task demands and the worker capabilities it is likely that the musculoskeletal system may become physically overexerted. Secondly, due to the nature of pushing and pulling tasks, they are associated with an increased likelihood of slip, trip and fall accidents, which can cause injuries to the musculoskeletal system.

The AWHR, TCCW and PCW data in Table 2 demonstrates that the use of SWHT and DWHT for carrying load of 5kg, 10 kg, 15kg and 20kg was better option than carrying it using traditional method. The PCW of male and female respondents was lower when they used SWHT (5kg- male 24.82 beats and female 27.99 beats; 10kg- male 25.22 beats and female 30.37 beats; 15kg- male 28.54 beats and female 30.36 beats and 20kg- male 29.93 beats and female 32.16 beats) in place of traditional method (5kg- male 29.97 beats and female 32.67 beats; 10kg- male 31.64 beats and female 37.22 beats; 15kg- male 32.48 beats and female 35.01 beats and 20kg- male 34.86 beats and female 37.38 beats) and DWHT (5kg- male 21.72 and female 26.18 beats; 10kg- male 24.58 beats and female 28.54 beats; 15kg- male 26.95 beats and female 30.01 beats and 20kg- male 29.76 beats and female 31.92 beats) instead of SWHT.

The AWHR, TCCW and PCW data of male respondents was lower than female respondents when they used either traditional method or improved material handling technologies that is, DWHT and SWHT. It can be concluded on the basis of AWHR, TCCW and PCW that DWHT for carrying load is better substitute of carrying load than SWHT and SWHT is better option than traditional method.

CONCLUSION

This research is important because with relatively low cost technology interventions some MSD risk factors that are inherent in the tool design, working environment, and the task itself can be remedied. This clearly establishes that the designed technology for material handling was much better than the traditional method of head loading and DWHT was better than SWHT. Thus, it can be concluded that use of mechanical aids reduces discomfort and physiological cost of work.

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