

Ergonomic assessment of hand cow milking operations in Khuzestan province of Iran

Abdullah Hayati*, Afshin Marzban, Mohammad Amin Asoodar

(Department of Agricultural Machinery Engineering and Mechanization, Ramin Agriculture and Natural Resources University of Khuzestan, Mollasani, Khuzestan, Iran.)

Abstract: Whereas mechanization and automation are developed in farm works especially in dairy farm working, hand milking method that includes physically demanding tasks is still very current among dairy farmers in Iran. The aim of present study was to assess the physically demanding nature of hand milking method including “washing the teats” and “milking”. Ten male workers were selected to evaluate their cardiorespiratory and energy-based demands. Results revealed that working heart rate (HR work) of washing the teats and milking operations were 90.7 and 104.3 beats/min respectively. Energy expenditure rate (EE) of milking was about 1.4 times higher than washing the teats and operation’s energy expenditure (OEE) of the milking was about 36.4 times higher than washing the teats. Milking operation occupied a higher proportion of total cycle time (5.37 min) than washing the teats (0.2 min). It could be said because of enhancing cycle time (as first factor) and enhancing heart rate (as second factor) interfered with OEE-enhanced milking operation in hand milking method. The present study shown hand milking method in dairy farm can be categorized as moderate work in the case of heart rate, and light work based on Borg scale.

Keywords: Ergonomics, energy expenditure, heart rate, heart rate ratio, perceived exertion, hand milking.

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1 Introduction

Agriculture as a major economic activity is one of the most hazardous sectors in both the developing and the developed worlds (ILO and IEA, 2012). Workers in agriculture face immense challenges regarding occupational safety and health. They often work under hazardous conditions and face adversities (Niu and Kogi, 2014). Despite widespread mechanization and automation in every field, farm work still includes several physically demanding tasks and human power is still one of the major contributors of energy for agricultural activities in developing industries (Tuure, 1992; Perkiö-Mäkelä and Hentilä 2005; Tiwari et al., 2011; Ismaila et al., 2013).

Each segment of production agriculture which is divided into animal production and field crops production requires intensive hand work (Kirkhorn et al., 2010). In this case Govindarajoo et al. (2014) introduced three factors as the ergonomics problems in a plantation which were environment, task and tools used in the plantation. Research studies suggest farm works are physically demanding in operations related to the poultry sector, mounding and ridging (Astrand and Rodahl, 1986; Dada and Abiola, 2010; Wang et al., 2012; Srivastava and Vats, 2012; Ismaila et al., 2013). Tuure (1992) also reported job of making a load of bales to a trailer represented highest level with respect to energy consumption and rate of perceived exertion (RPE) than jobs of lowering tomatoes in standing position and mechanized loading and transportation of timber. In the case of rice transplanting Ojha and Kwatra (2012) concluded that manual uprooting and transplanting is more physically demanding activity as compared to their mechanical performing.

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*Corresponding author: Abdullah Hayati, Department of Agricultural Machinery Engineering and Mechanization, Ramin Agriculture and Natural Resources University of Khuzestan, Mollasani, Khuzestan, Iran. Tel.: (+98) 9168934320, Fax: (+98) 6123223922. Email: abd.hayati@yahoo.com.

In dairy farm sector the milking machines as one of the agricultural mechanizations are most important means of reducing worker requirements (Clough, 1963). The use of automatic milking systems such as mechanized teat cleaning (De Koning, 2010), milking parlor (Hwang et al., 2010) and a milk pipe line that eliminates carrying heavy buckets (Vos, 1974) have all contributed to mechanization of milking system and to the decrease in physical demanding of the milking workers.

In general, mechanization ends to decrease the physical load of the worker (Perkiö-Mäkelä and Hentilä 2005), even though mechanization of the milking process still leaves many hand operations to the milking worker (Vos, 1974). Groborz et al. (2011) concluded from their investigations that a higher level of farm mechanization does not always mean that the farmer's postural load is lower. In this case Shkulov et al. (1980), Ahonen et al. (1990), Nevala-Puranen (1996), Perkiö-Mäkelä and Hentilä (2005) and Hwang et al. (2010) also reported physically demanding activities in dairy farm milking operations. Stal et al. (2000) revealed the transition from tethering to loose housing systems reduces for the upper extremity peak loads, but increases the static load and reduces muscular rest. Results from study of Patil et al. (2010) suggested that dairy parlor work is stressful to the upper extremity.

While the official statistics are not available for quantitative and qualitative dairy farms that use hand milking in Iran, this method is very common among dairy farmers. In hand milking method the worker works in squat posture and the tasks involve human muscle power and is a heavy physical work (European Commission, DG Employment, Social Affairs and Equal Opportunities, 2008). In Iran the use of manpower may likely persist in occupations such as dairy farm work, where approximately 55% of labour's time is expended in the milking operation (Bickert et al., 1974). Thus milking operation is very important in respect of human energy expending factors.

The energy that human body requires to maintain its organic and vital functions is obtained by the oxidation of macronutrients from foods (Diener, 1997; Pinheiro Volp et al., 2011). Total energy expenditure (TEE) is comprised of three main components: the basal energy expenditure (BEE), diet induced thermogenesis (DIT), and the energy expended in physical activity (EE) (Yu et al., 2012). Energy expenditure as one aim of our study represents the thermic effect of any movement (Pinheiro Volp et al., 2011).

Although hand cow milking method is very common in Iranian dairy farm, ergonomic assessment of this method is little or no-considered in this country. In addition few studies were performed in the case of human energy and cardiorespiratory demanding for hand milking method. This study attempts to evaluate physically demanding hand milking method using, heart rate (HR) as energy expenditure in physical activity (EE).

2 Material and methods

2.1 Manual workers

Ten male manual workers, whose ages were 35 (± 3.2) were chosen randomly from the population. Physical characteristics of workers in milking methods are shown in Table 1. The workers were used to acute musculoskeletal symptoms and their full consents to participate in the study were sought. All of workers were right handed. All of them were of normal weight (body mass index (BMI 18.5–24.9 kg/m²)) based on WHO (2000) categorization. These physiological characteristics were recorded in the afternoon shift at temperature between 36 °C and 41 °C. Hand milking operations included “washing the teats” (time: 0.2 min) and “milking” (time: 5.37 min). Two mentioned times were achieved by average of 20 observations for each operation. In washing the teats worker only takes a little water from a calix and washed the teats associated massage and pressure. In the milking worker teat-milked the cow with hand, and it was obvious that this operation taken more time than washing the teats. Milking operations was performed in two shifts

on Holstein cows with about 5.4 kg milk per afternoon shift.

Table 1 Physical characteristics of workers in hand milking

Variable	Quantity
No.	10
Sex	Male
Age (yr)	35 (± 3.2)
Height (cm)	172.3 (± 2)
Weight (kg)	67.3 (± 5.2)

HR was measured with a Beurer PM 45 (Beurer, Germany). The signals were transferred from the Beurertransmitter (consist of two sensors) which was putted on the chest of worker by a tension strap, to the heart rate monitor. The heart rate ratio (%HRR) was calculated with the following equation: $100 \times (\text{HR}_{\text{work}} - \text{HR}_{\text{rest}}) / (\text{HR}_{\text{max}} - \text{HR}_{\text{rest}})$ (Karvonen et al., 1957; Louhevaara et al., 1985). Maximal heart rate (HR_{max}) was calculated as $205.8 - 0.685 \times \text{Age}$ (Inbar et al., 1994). Heart rate at work (HR_{work}) was measured during different work tasks. Heart rate at rest (HR_{rest}) was measured after 5 min of as worker with the resting in a reclining position (Perkiö-Mäkelä and Hentilä 2005). The rate of perceived exertion (RPE) was rated after every work task on the Borg RPE 20 scale, ranging from 6 to 20 where 6 means “no exertion at all” and 20 means “maximal exertion”. While doing physical activity, it was wanted worker to rate his perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to worker. From median exertion levels and up to this level, in people range 25 to 45 years ago, heart rate number is approximately ten times of RPE scale number (Borg, 1970). Twelve observations were performed for HR_{work} and HR_{rest} of each worker in each operation and the RPE value was asked three times for each worker through total time of hand milking. Ergonomic data (HR_{work} , HR_{rest} and RPE) were collected in six repetitions of hand milking operations.

The energy expenditure during physical activity (EE) of milking was determined using the following equation for male: $-55.0969 + 0.6309 \times \text{HR}_{\text{work}} + 0.1988 \times \text{Weight} + 0.2017 \times \text{Age}$ (Keytel et al., 2005). In addition, energy expenditure of operation (OEE) for each worker and energy expenditure of operation per body mass (MEE) for each worker, were calculated. OEE is energy expenditure of operation without considering differences and diversities of workers with regard to their body mass (weight). MEE is calculation of OEE of each worker per body mass. So, according above equation, for example actual differences of two workers with same or near together age and HR_{work} , but considerable different-weights were indicated by MEE clearer than OEE because a proportion of OEE-increasing in heavier worker was caused his higher body mass which was not caused by energy-demanded increasing of the task. Related this case, it should be said objective of this study was assessing the work energy-demanded, not the worker energy-demanded.

The data handling was carried out using the SPSS 16.0 program. The ANOVA and independent samples t-test were used to compare the group means. A value of $p < 0.05$ (two-tailed) was regarded as statistically significant.

3 Results

3.1 Results of cardiorespiratory assessment

As shown as Table 2 the data revealed that working heart rate (HR_{work}) of washing the teats and milking operations in hand milking were 90.7 and 104.3 beats/min respectively. There were significantly differences ($p < 0.05$) between washing the teats and milking with respect to HR_{work} . Total heart rate of hand milking was obtained 103.8 beats/min. Percentage of the heart rate ratio (%HRR) was higher in milking by 35.8% than washing the teats at 24.4%. Results of linear regression analysis showed significant relation ($p < 0.001$) existed between heart rate and perceived exertion as in the following equation: $\text{RPE} = 0.116 \times \text{HR}_{\text{work}} - 0.9$ ($R^2 = 0.739$).

Table 2 Heart rate at work (HR_{work}), heart rate ratio (HRR) and rate of perceived exertion (RPE) of workers in hand milking operations

Operation	HR_{work} (beats/min)	HRR (%)	RPE
Washing the teats	90.7 (± 4.1)	24.4 (± 1.5)	
Milking	104.3 (± 2.3)	35.8 (± 1.4)	
Total*	103.8 (± 2.3)	35.3 (± 1.4)	11.1 (± 0.3)

Note: * Corresponding total cycle of hand milking operation including "Washing the teats" and "Milking".

3.2 Results of energy demanding

The EE, the MEE and the OEE were higher during milking by 1.4, 35 and 36 times, respectively compared to washing the teats (Table 3). These changes were statistically significant. Total energy expenditure in operations (OEE) was also 171.3 kJ which was occupied 97.7% of this characteristic by the milking operation. In addition mentioned operation plundered 98% of total MEE.

Table 3 Characteristics of energy expenditure (EE) of workers in hand milking operations

Operation	Characteristics		
	EE (kJ/min)	MEE ² (kJ/kg)	OEE ¹ (kJ)
Washing the teats	22.6 (± 0.9)	0.07 (± 0.01)	4.6 (± 0.2)
Milking	31.2 (± 1)	2.45 (± 0.29)	167.3 (± 5.3)
Total*	30.9 (± 1)	2.56 (± 0.9)	171.3 (± 5.4)

Note: *Corresponding total cycle of hand milking operation including "Washing the teats" and "Milking".

1-OEE: energy expenditure of operation; 2-MEE: energy expenditure of operation (OEE) per body mass.

4 Discussion

Using the classification of Astrand and Rodahl (1986), operation of washing the teats and milking could be regarded as moderate work in terms of mean heart rate. Perkiö-Mäkelä and Hentilä (2005) also reported milking was light work and feeding was moderately heavy for the cardiorespiratory system of the farmers, who worked in loose housing barns. Because the heart rate is accounted as one of the factors for work load (Saebi Monfared and Sedaghat Hosseini, 2006), thus operation of milking caused an enhanced work load compared to operation of washing the teats. The milking operation heart rate was greater than washing the teats, because the time of the milking operation occupied a higher proportion of total cycle time than washing the teats (5.37 min vs 0.2 min).

The rate of perceived exertion (RPE) of workers in hand milking operations was 11.1 (Table 2). The relative quantity suggested hand milking operations was light work based on Borg scale. Hashemi (1995) also reported works related milking operation performed without any heavy workload.

Total EE of hand milking operation in this study was 30.9 kJ/min. Mean energy expenditure was also suggested in ancillary operations and hand milking respectively 14.3 ± 0.4 and 14.3 ± 0.4 kJ/min (Shkulov et al., 1980). In present study the characteristics of energy expenditure of workers were higher in milking compared to washing the teats. This was occurred because of enhanced heart rate and cycle time of the milking compared to other operation. Energy expenditure of operation of the milking also was about 1.4 times higher than washing the teats, whereas operation of the milking was about 36.4 times higher than washing the teats with regard to OEE. Thus, cycle time of the milking was the first and more important factor and heart rate was the second factor interfered in OEE-enhanced milking operation in hand milking method.

5 Conclusions

From the present study, hand milking method in dairy farm can be categorized as moderate work with respect to heart rate and light work based on Borg scale. The work load of milking was higher than washing the teats based on heart rate. Energy expenditure of workers was higher in the milking operation compared to washing the teats because of enhancing cycle time (as first factor) and enhancing heart rate (as second factor) of the milking compared to other operation.

This study involved male workers. It is obvious that results of cardiorespiratory and energy expenditure analyses of female workers may be different. Thus other studies are required for both male and female workers in the milking method.

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