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Musculoskeletal Disorders, Energy Use, and Costs of Human Labor for Paddy Cultivation in Northern Iran

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Abstract

In this study, musculoskeletal disorders, energy consumption and input costs of paddy labors have been studied in cultivation, crop protection, and harvesting rice in Northern Iran, Guilan province. The sample size of the study consisted of 74 paddy workers of the study region. The data were collected through Nordic questionnaire and semi-structured interviews. The results indicated that the labor input energy of cultivation, crop protection, and harvesting were 674.6, 356.8 and 205.9 $MJha^{-1}$, respectively. The total labor input costs were determined to be 22,860,000 IRRs ha^{-1}. Lower back, back and knees were the most common areas where paddy workers were feeling pain. There were significant differences among the age, working hours and working years of healthy and relatively healthy poor paddy workers ($p<0.01$). One-fifth of the selected farmers self-reported that their health was at a very poor level. Overall, considering the relatively high costs and the different types of common musculoskeletal disorders related to rice cultivation in this province and also the side effects of using the painkillers in the working season, it is recommended to invest and accelerate the process of mechanization of rice farming in Guilan Province of Iran.

Keywords:
energy, ergonomics, human labor, paddy workers, Rice

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INTRODUCTION

The reduction of production costs, increasing the amount of crop yield and promoting the quality of workers' life are the main incentives for moving towards agricultural mechanization (Almasi et al., 2008; Fallahi et al., 2016). However, agricultural operations may sometimes lead to a number of musculoskeletal disorders. An ergonomic agricultural machine can significantly decrease such negative effects.

According to the European Commission report, more than 4% of the worldwide Gross Domestic Production (GDP) was wasted due to accidents and illnesses related to tough working conditions (Takala & Niu. 2003; Niu, 2010). Moreover, agricultural workers in developing countries are faced with even more musculoskeletal disorders during agricultural operations. Hence, it is necessary to pay more attention to the occupational health of agricultural workers in developing countries.

There have been several studies on the ergonomic condition of agricultural workers. Javidi-Gharache and Khojastehpour (2016) studied the ergonomic situations of tea farmers in the northern parts of Iran during plucking. It was reported that the highest prevalence rates of musculoskeletal pains or discomforts were in the trunk region (92%), followed by the neck and upper arm (38%), lower arm (23%), and wrist (15%). Jyotsna et al. (2005) investigated the ergonomic condition of female rural workers involved in wheat harvesting. The average heart rate of the subjects was found to be 121.5 beats min^{-1}, which increased up to 126.7 beats min^{-1} at the end of the activity in the evening. In addition, energy expenditure was found to be 10.5 kJ min^{-1}, which increased up to 11.2 kJ min^{-1} during evening hours.

On the other hand, high input costs and energy consumption of human labors for producing agricultural products is an important concern in developing countries. In recent years, some studies have evaluated the energy flows of agricultural products, such as peanut (Emadi et al., 2015), canola (Taheri-Garavand et al., 2010) and watermelon (Mohammadi-Barsari et al., 2016) in the Northern parts of Iran.

With an estimated 564,000 hectares of cultivation area, rice (*Oryza sativa* L.) is the second most important food crop in Iran (FAO, 2013). Approximately, 238,000 hectares of rice are cultivated in Guilan Province (Ministry of Jihad-e-Agriculture of Iran, 2014), making it one of the most important rice-producing regions in the country (Zareiforoush et al., 2010; Nasirahmadi et al., 2014). The sustainable production of rice in Guilan Province of Iran requires the consideration of human labor productivity at all the stages of the production systems. However, to the authors' best of knowledge, no previous analytical study has been conducted on the musculoskeletal disorders, energy use and costs of human labor for rice production in Guilan Province of Iran. Therefore, the aim of the present study was to investigate the musculoskeletal disorders, energy use and costs of human labor for rice farming in Guilan Province, Iran.

MATERIALS AND METHODS

The case study and data collection

This study was conducted in three regions of Khomam, Khoshkebijar, and Lashtenesha regions in Guilan Province during farming season of 2013. Cochran methodology was used to determine the sample size (Eq. 1.). As a result of this calculation, the data were collected from 74 rice farmers by personally handing out the questionnaires.

$$n = \frac{N(s \times t)^2}{(N-1)d^2 + (s \times t)^2} \quad (1)$$

Where, n = sample size, N = number of holdings in the target population, t= the reliability coefficient (1.96), s = the variance, and d = precision (Snedecor & Cochran, 1989).

Energy and cost analysis

The equation 2 was used to determine the energy consumption of human labor. The energy equivalences of female and male workers were considered as 1.57 and 1.96 $MJha^{-1}$ (Singh et al., 1994).

$$E_{labor} = EI_{labor} \times t \quad (2)$$

where, Elabor= energy consumption of human labor (MJ ha^{-1}), EIlabor = Human labor energy equivalence (MJ hr^{-1}), and t = the human labor used (hr ha^{-1}).

Musculoskeletal disorders analysis

Nordic questionnaire was used to evaluate the musculoskeletal disorders of rice farmers in Guilan Province, Iran. The BMI index as a measure of body fitness is calculated as (Jaworowska & Bazylak, 2009):

$$BMI = W/L^2 \quad (3)$$

where W (kg) and L (m) are the weight and the height of the labor, respectively. If this index is less than 18.5, it indicates that the person is under-weighed, The BMI of 18.5 to 24.9 shows that the person has a normal body composition, and a BMI of over 25 and 30, indicate overweight and obesity, respectively (Fallahi et al., 2016).

The means comparison between healthy and unhealthy subjects was performed using paired-samples *t test* and Wilcoxon signed ranks (Andries et al., 2011; Colasanti et al., 2012). All the calculations were conducted using Microsoft Excel 2007 and JMP8.

RESULTS AND DISCUSSION

Energy consumption and input costs

Table 1 shows the energy consumption and input costs for rice production chain (transplanting, crop protection, and harvesting) in Guilan Province, Iran. The female and male labors used for preparing the farms to cultivate and transplant a hectare were determined to be 133.2 and 237.5 h, respectively and their costs were calculated as 3,330,000 and 8,906,250 IRRs[1] , respectively. The total energy consumption of human labor for cultivation was 674.6 MJha^{-1}. The human labor used for crop protection was less than that of cultivation. The total cost of human labor and its energy consumption for crop protection were determined to be 194.8 h and 6,110,170 IRRs ha^{-1}. Moreover, 28% of the total amount of energy consumption during crop protection (356.8 MJha^{-1}) was attributed to female laborers. The total cost of human labor for harvesting was 4,516,250 IRRs ha^{-1}.

The total human labor used for rice production was 647.7 h ha^{-1}. Human labor consumption for peanut production in Guilan Province of Iran was reported to be 641.12 h and peanut harvesting is performed manually in this region (Nikkhah et al., 2015). However, the human labor used for rice production in this region was higher than that of peanut production. The total cost of human labor for rice production was obtained 22,680,000 IRRs ha^{-1}. Moreover, its energy consumption for rice production was 1237.3 MJ ha^{-1}. Pishgar-Komleh et al. (2011) studied rice production in Guilan Province of Iran in the time period of 2009-2010. They showed that the total amount of energy consumed for rice production was 1315 MJha^{-1}. There were no differences between the amounts of human labor consumption reported by Pishgar-Komleh et al. (2011) and the values determined in this study. Payman et al. (2006)

Table 1
Energy Consumption and Input Costs of Rice Production Chain

	Land preparation and transplanting			Plant protection			Harvesting		
	Human labor (h)	Energy consumption (MJ)	Cost (IRRs)	Human labor (h)	Energy consumption (MJ)	Cost (IRRs)	Human labor (h)	Energy consumption (MJ)	Cost (IRRs)
Female	133.2	209.1	3,330,000	64.1	100.6	2,515,920	20.9	32.8	653,120
Male	237.5	465.5	8,906,250	130.7	256.2	3,594,250	88.3	173.1	3,863,120
Total	370.7	674.6	12,236,250	194.8	356.8	6,110,170	109.2	205.9	4,516,250

[1] *IRR is the abbreviation for Islamic Republic of Iran Rials, which is the currency used in Iran ($1=32000 IRR).*

Table 2
Different Types of Operations for Paddy Production in Guilan Province of Iran

	Land preparation and transplanting		Crop protection		Harvesting		
	Manual	Transplanting machine	Manual	Machine	Manual	Harvester	Combine
Numbers of farms	71	3	74	0	66	7	1
Percent	95.95	4.05	100	0	89.19	9.46	1.35

claimed that mechanization of rice cultivation could decrease the human labor consumption in the rice production chain.

The amounts of labor energy consumption for soybean, canola and sunflower production in Iran were reported to be 450, 155 and 300 $MJha^{-1}$, respectively (Ramezani et al., 2011; Mousavi-Avval et al., 2011a; Mousavi-Avval et al., 2011b). Human labor energy consumption for canola production in Mazandaran Province was reported 70.84 $MJha^{-1}$ (Taheri-Garavand et al., 2010). All were less than that of rice production in this study.

Musculoskeletal disorders in rice farming

Table 2 displays the different types of operations for rice production in Guilan Province of Iran. Approximately, 96% of the farms in this region are cultivated manually, which indicates that only 4% of the farmers in Guilan Province use transplanting machines for rice cultivation. Weed control was performed manually in all the studied farms. In order to use weed machines, the farms should be cultivated by machines. As for harvesting, the shares of manual harvesting, harvester and combine were determined to be 89.19%, 9.46% and 1.35%, respectively.

Figure 1 demonstrates the farmers' attitudes towards the hotspots of musculoskeletal disorders in paddy cultivation. Overall, 51.35% of the framers announced that harvesting was one of the main causes of musculoskeletal disorders for rice production in Guilan Province, 48.69% believed that the activities related to cultivation are the hotspot for musculoskeletal disorders, while only 29.73% of the framers claimed that weed control operation is the main cause of musculoskeletal disorders. Female laborers who had more contribution to the cultivation operation claimed that cultivation is the main cause of musculoskeletal disorders resulting from rice production chain.

Table 3 shows the main parts of the paddy worker's body which are subjected to the stress during paddy cultivation. Based on the farmers' self-report, lower back and back parts were the most common areas under stress during rice farming. More specifically, 48% of the female and 52% of the male labors had pain in their backside, lower back and back after performing

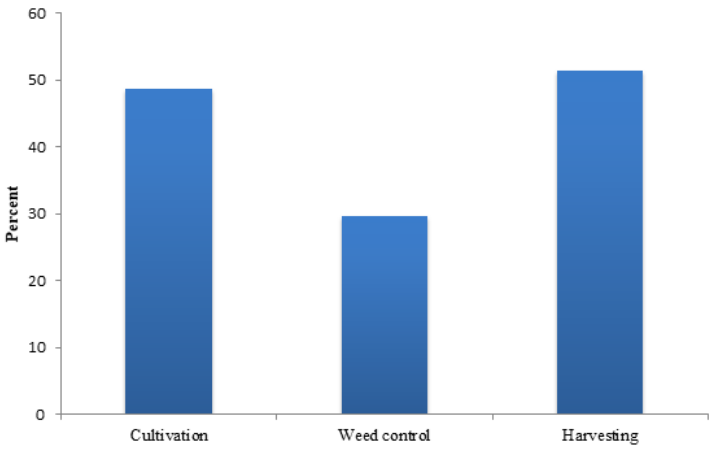

Figure 1. The farmers' comments about the main causes of musculoskeletal disorders in paddy cultivation

Table 3
The Body Parts of Paddy Workers Which Are Subjected To Stress during Paddy Cultivation

Musculoskeletal disorders	Neck		Shoulders		Elbows		Wrists and hands.		Back		Backside and lower back		One or both thighs		One or both knees		One or both feet	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Gender	21	17	15	20	19	12	25	22	17	19	31	29	15	18	24	24	22	24
Percent	55	45	43	57	61	39	53	47	47	55	52	48	45	55	50	50	48	52

agricultural operations. Knees were determined to be the third areas which were under the highest amount of stress during rice production. About half of farmers reported pain in this area. These results are in line with the results reported by Ojha and Kwatra, (2012) for manual transplanting among 20 subjects in India.

According to the data collected in this study, wrists, hands, and feet are also the areas that are remarkably damaged as a result of paddy cultivation chain. Also, 72% of the farmers reported that they have referred to a medical clinic (at least once) for pains resulting from agricultural activities and 90% of them announced that they feel pain after each day of performing agricultural activities. Surprisingly, 87.84% of the farmers in this study were not trained for performing the agricultural activities in a correct and ergonomic way. Therefore, implementation of ergonomic training classes to promote the ergonomic condition of rice farmers in this region seems to be an urgent need. Sadeghi et al. (2013) evaluated the effects of an ergonomic training program on saffron workers. They found that before the ergonomic training program, 70% of the farmers had poor health conditions. However, after participating in an ergonomic training program, this number reduced to 50%.

Table 4 indicates the means comparison of some characteristics of healthy and unhealthy subjects. The differences between the ages of the healthy and unhealthy subjects were not significantly different at the 5% level. The average age of the unhealthy participants was 50 years. The difference between the ages of the healthy and unhealthy subjects was not statistically significant; however, the height difference between the two groups was significant.

Table 4
Means Comparison of Some Characteristics of Healthy and Unhealthy Subjects

Variable	Physical condition	Average	t-statistic	Variable
Age (year)	Healthy	39.92	3.09	0.003
	Unhealthy	49.83		
Weight (kg)	Healthy	69.52	-0.817	0.416
	Unhealthy	71.60		
Height (cm)	Healthy	168.88	-2.02	0.047
	Unhealthy	164.02		
BMI index (kg m^{-2})	Healthy	25.21	0.74	0.464
	Unhealthy	26.02		
Working hours (h)	Healthy	7.78	2.70	0.009
	Unhealthy	9.81		
Agricultural employment background	Healthy	15.36	3.41	0.001
	Unhealthy	26.27		

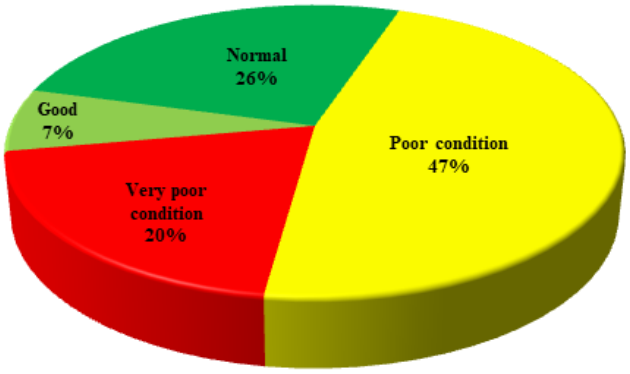

Figure 2. The farmers' comments about their healthiness

The difference between the working hours of the healthy and unhealthy subjects was statistically significant at 1% level. Unhealthy subjects dedicated more hours per day to performing agricultural activities compared to the healthy subjects. The average working hours among unhealthy subjects was 9.81 hours per day^{-1}. However, healthy subjects worked for less than 8 hours a day. Therefore, it is recommended that farmers avoid doing agricultural activities for more than 8 hours per day.

The results of Wilcoxon signed ranks did not indicate a significant difference between the healthiness of female and male laborers at the 5% level (Z= -0.78, p= 0.44). With regard to the manual harvesting of paddy rice in Iran by male laborers, they are exposed to some work-related physical risks.

Figure 2 shows the farmers' comments about their healthiness. Accordingly, 20% of the farmers evaluated their healthiness on the very poor condition level and 47% of them announced that they were working under weak work-related conditions. The remarkable point is that some farmers claimed that they use painkiller drugs before each work shift to cope with tough working conditions. Due to the poor work-related conditions of rice farmers in Guilan province of Iran and the high costs of manually performing agricultural activities, it is recommended that the beneficiaries, including farmers, authorities, etc., support the designing of a number of new and ergonomic agricultural machines, especially a transplanting machine, to improve the working conditions of laborers.

CONCLUSION

This study aimed to evaluate the musculoskeletal disorders, energy use, and costs of human labor of paddy cultivation in the Northern regions of Iran. The highest prevalence rates of musculoskeletal pain or discomfort were in the backside and lower back, followed by the back area. There was a significant difference between the working hours of the healthy and unhealthy subjects at 1% level. Unhealthy subjects assigned more hours per day to agricultural activities compared to the healthy subjects. Also, 20% of the farmers in this study evaluated their healthiness under a very poor condition and 47% of them claimed to be working under weak work-related conditions. Due to the poor work-related conditions of rice farmers in Guilan province of Iran and the high costs of manually performing agricultural activities, it is recommended that the beneficiaries, including farmers, authorities, etc., support the designing of a number of new and ergonomic agricultural machines, especially a transplanting machine, to improve the work conditions of laborers.

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