Assessment of Ergonomics of Farming Activities for Backyard Vegetable Production in the North Western Ethiopia: Case of Dangishta Community

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Abstract. A problem of improving crop productivity is usually related to poor agronomic practices and scarce water resources but the poor gap in use of appropriate technologies within the farming system has also a role. In order to modify and design ergonomically safe, affordable, efficient and friendly tools that improving the farming system, task analysis is needed which is not done usually in within the agricultural system of Ethiopia. This paper presented analysis of farming tasks for vegetable production using local tools in Ethiopian during dry period garlic production in Dangishita Kebele. The study was performed by interviewing 32 women farmers. In addition, three women farmers were used to do task breakdown, postural ergonomic risk assessment. Farming tasks such as soil preparation, seedling, irrigation and harvesting were complained by farmers for causing pains on different body parts. The most affected body parts during dry period irrigation farming practices were lower back, elbow, shoulder, wrist, neck and knee. Farm task analysis showed that the risk severity from soil preparation and irrigation tasks were serious and needed alternative intervention to reduce the risk. Possible solutions include conservation agriculture, adopting ergonomic tools for soil preparation, and adopting of drip irrigation system. As a result, these will affect the productivity and quality of farm production besides affecting safety and health condition of farmers.

Keywords: Ergonomics · Postural ergonomic risk assessment · Task analysis · Body parts discomfort rate

1 Introduction

As stated by Mekuria (2018), Ethiopia is one of the least developed countries in Sub-Saharan Africa with nearly 100 million people, of which 80.5% of the rural population

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is relied on agriculture for their livelihoods. However, there are still major gaps between farmers' yield and exploitable yield due to limited use of technological packages and inputs. As identified by Birara et al. (2015), population pressure, poor soil fertility, land shortage, high labor wastage, poor farming technologies, pre and post-harvest crop loss, poor social and infrastructural situation and other factors have caused the problem of food insecurity in Ethiopia.

Dagninet et al. (2016) have discussed the current status of Ethiopian farming system which is characterized as low and subsistence production, animals and human powered farm, use of less productive farm tools, high drudgery and work burden, high post-harvest loss, single employment field, low market orientation and less commercialization. According to FAO (2013), the production of food in developing countries is generally very labor intensive particularly in smallholder agriculture. Especially, women are the most affected group in Africa as the average female labor share in crop production during agricultural activities such as land preparation, planting, weeding and harvesting reaches to 40% in Sub-Saharan African countries (Palacios-lopez et al. 2017). The technological interventions in agriculture has not made much progress at all so that the problem of the agricultural activities being labor intensive is inevitable (FAO 2013). Many sub-Saharan African countries including Ethiopia are therefore looking for the application of scientific and technical methods of farming that can be adapted to their conditions.

From the literatures it was evidenced that the current statutes of technology adoption and utilization within Ethiopian farming system is much less and limited as compared to the developed countries. Mekuria (2018) suggested that the crops productivity levels of Ethiopian farming system can be increased significantly by improving the traditional farming practices and adoption of technologies. Similarly, FAO (2013) revealed in its report that there exist a large potential for improvement in agricultural productivity within Sub African countries including Ethiopia. Palacios-lopez et al. (2017) viewed that introduction of medium or low level mechanization implements and technologies enables lighten burden of women who contribute most of the labor for agricultural production in Ethiopia.

Therefore, it is highly recommended that Ethiopia need to adopt, modify and use appropriate scaled technologies or mechanized methods for improving labor productivity as well as human drudgery besides guarantying food security. Having recognized that introducing modern farming technologies for increasing productivity and solving food security problem, ergonomic evaluation is essential for its successful modification, effective application and efficient utilization by farmers. Ergonomics contributes to design and evaluation of farming tasks and farm tools in order to make them compatible with the needs, abilities and limitations of farm works.

Many researchers have attempt to show in their study how agricultural tasks can expose to ergonomic hazards and reduce productivity of farmers due lack of consideration of ergonomics in agriculture. For instance, Bernard et al. (1993) and Murphy (1992) explained that agricultural work involves risk factors associated with musculoskeletal disorders because field jobs (harvesting, weeding, irrigating, cultural practices, etc.) remain demanding physical tasks, involving stooped postures, lifting and carrying, and repetitive hand work. Meyers et al. (1998) mentioned three general risk factors as both endemic and of highest priority throughout the agricultural industry. They are: lifting and

carrying heavy loads, sustained or repeated full body bending (stoop) and very highly repetitive hand work (clipping, cutting). According to world health organization (1980) most musculoskeletal problem occurs in agriculture working cases due to excessive physical effort on the body, awkward postures, prolonged standing and kneeling, stooping, bending, and repetitive muscle activities. Chavalitsakulchai and Shahnavaz (1990), and Praveena et al. (2005) pointed out that women are the backbone of agricultural who does the most tedious and back-breaking tasks in agriculture but the problems of labor and hardship faced by women are less addressed in Africa.

According to Stanton et al. (2006), ergonomic task analysis procedure should consist five phases: recognition, video recording, subtasks separation, video analysis, and frame classification. Chander and Cavatorta (2017) explained that methods such as Ovako Working Posture Analysis System – OWAS, Rapid Upper Limb Assessment- RULA, Strain Index (SI), Rapid Entire Body Assessment – REBA, Quick Exposure Check – QEC and postural ergonomic risk assessment (PERA can be used to evaluate the degree of discomfort and overload of the musculoskeletal system caused by various postures of the human body during the work. André and et al. (2017) commented that postural ergonomic risk assessment (PERA) is better since the criteria developed for classification of demands of posture, duration and force clear and easy for applying.

Thus, the aim of this paper is to present research report done on ergonomic analysis using the approach of postural ergonomic risk assessment of agricultural tasks during dry home garden garlic production in Ethiopia, Amhara Region at Dangishita Kebele. Particularly, the result of such analysis is worth enough to help government of Ethiopia during making decision regarding to prioritization of introducing and adopting of agricultural technologies or mechanized methods for reducing human drudgery or ergonomic risk factors along with ensuring food security of the nation by improving agricultural productivity.

2 Methodology

The farming activities for garlic production in Dangishta community, West Gojam, Amhara regional state of Ethiopia have been analyzed starting from October 2017 till April 2018 for three consecutive months. The targets were women who were organized by the innovational lab for sustainable intensification project to produce garlic in their home garden using hand dug shallow ground water wells (Fig. 1).

The study was basically performed by using field survey through structured interview and video recording technique. Thirty-two women farmers having an age between 24–55 years were interviewed using a modified Nordic musculoskeletal disorder questionnaire for assessing body parts discomfort or pain feeling during farming tasks and identifying tasks that were most complained by farmers.

The study used three selected women farmers for intensive video recordings while they were in real situation of performing their farming tasks to break down in to key activities. The video used in this data collection was Fujifilm X100F Digital Camera – Silver. Moreover, videotaping of farming tasks is necessitated for understanding the working posture, physical force exertion or nature of motions and task time. Estimated average time for each key activities of farming tasks and total task time taken were

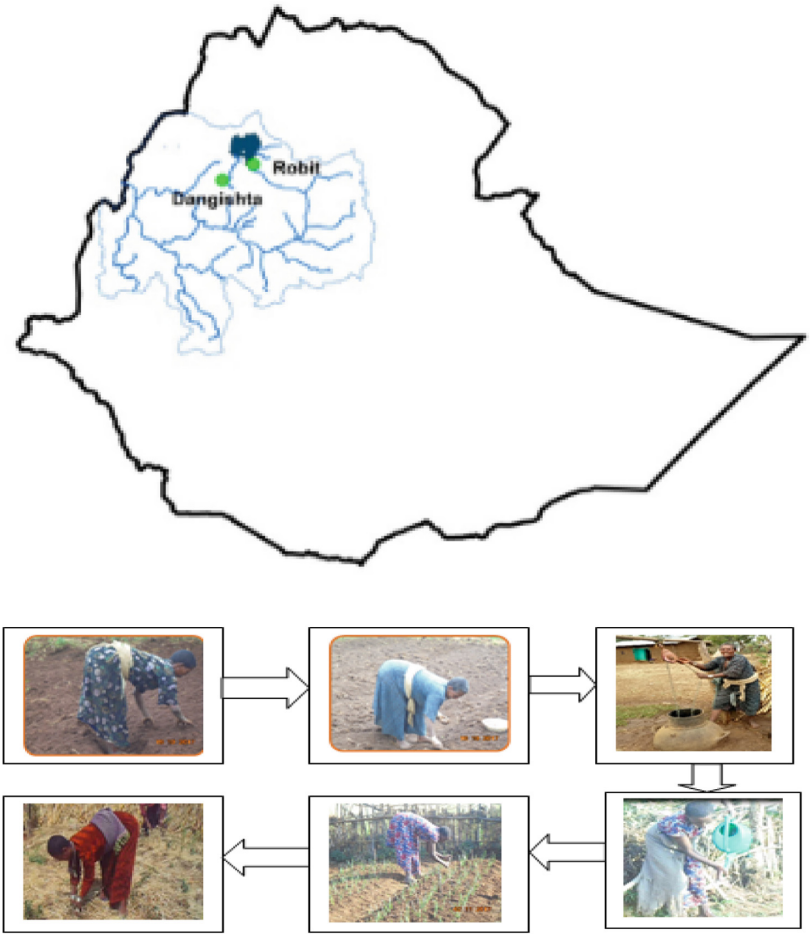

Fig. 1. Location of the study area Dangishta in Ethiopia and the farming tasks considered in the study (soil preparation, seed planting, ground water lifting, manual irrigation, weeding and harvesting)

obtained from slow motion playing of recorded videos during performing the tasks. Here, 10 trials for each estimation were considered.

Ergonomic risk level estimation for farming tasks were conducted by using postural ergonomic risk assessment (PERA) method. The risk scores for each activity were estimated based on the risks level classification criterion for activity duration developed by Chander and Cavatorta (2017) and supported with postural ergonomic risk assessment (PERA) method. According to PERA method overall ergonomic risk score for work task was obtained as the product of risk of physical effort, risk of task duration (time percentage) and risk of working posture. The risk from exertion of physical effort was estimated by observing the nature of the workers' motions. Positions of workers' trunk, hand, neck and shoulder were considered to estimate the ergonomic risk level due to

working postures. The risks level related to duration was judged by considering the time percentage of total time taken for task.

3 Results and Discussion

It was observed that women were accomplishing all agricultural tasks beginning from soil preparation up to transporting the farm yield to home and market place. The women workers attained various working postures, exert forces and work continuously until they accomplished the agricultural tasks.

3.1 Body Parts Discomfort Feeling Assessment

Body discomfort assessment during five months based on women farmers' response rate was considered in Table 1. It was reported that highest number (100%) of the respondents perceived discomfort or pain to lower back of their body part and least number (38%) of respondents perceived pain related to hip body parts.

Table 1. Body parts discomfort assessment during farming tasks

Sr. No.	Body parts affected	No. of women's responses	% of women's responses
1	Neck	26	81%
2	Shoulder	26	81%
3	Elbow	30	94%
4	Wrist/hands	26	81%
5	Upper back	14	44%
6	Lower back	32	100%
7	Hips	12	38%
8	Knees	24	75%
9	Ankles/feet	18	56%

Using women farmers' response rate, pareto analysis for identifying body parts of farmers that were most affected during farming activities was conducted. The result showed that almost 80% of the body discomfort or pain was caused due to stress on lower back, elbow, shoulder, hand, neck and knee are most affected body parts respectively (Fig. 2).

It was also reported that women farmers complained about the various agricultural activities they performed and the possible pains or body parts discomforts associated with the tasks. Accordingly, 47% of respondents told that they experienced lower back pain or discomfort during soil preparation task, while 41% of respondents feel lower back pain or discomfort associated with seedling task. Nearly 47% of women farmers complained shoulder pain or discomfort during irrigation of the farm area. 34%

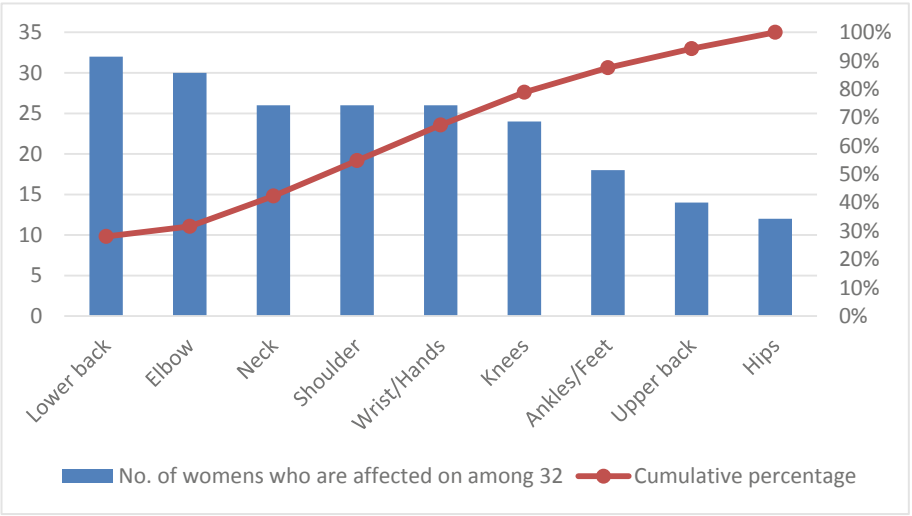

Fig. 2. Body discomfort assessment during farming activity

of respondents experienced Wrist/hands pain or body parts discomfort associated with weeding activities. Another 22% of respondents informed that they complained harvesting and post harvesting tasks for causing neck, wrist/hands and lower back pain or body parts discomfort feeling.

Based on women farmers' response rate, body parts discomfort rate was assessed and prioritized during each farming activities. Thus, as shown in Fig. 3 it was found that farming tasks of soil preparation, overhead irrigation and weeding tasks have more ergonomic hazard.

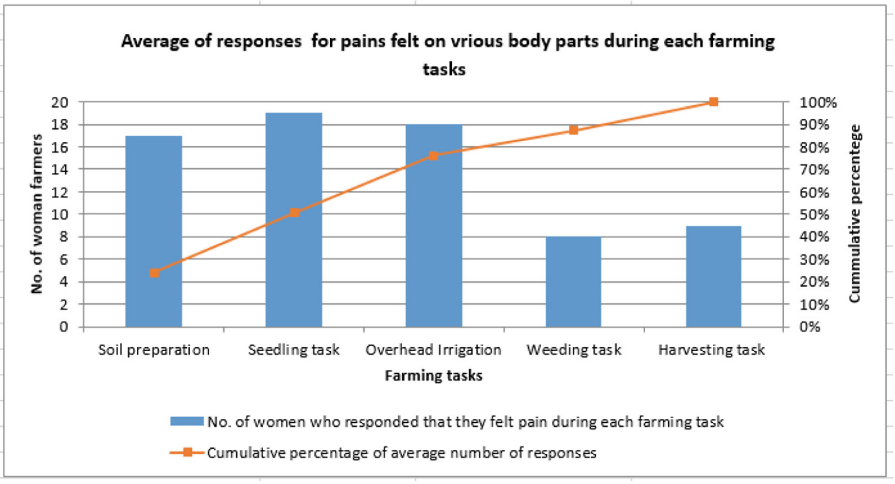

Fig. 3. Farming tasks complained for feeling of pain on different body part

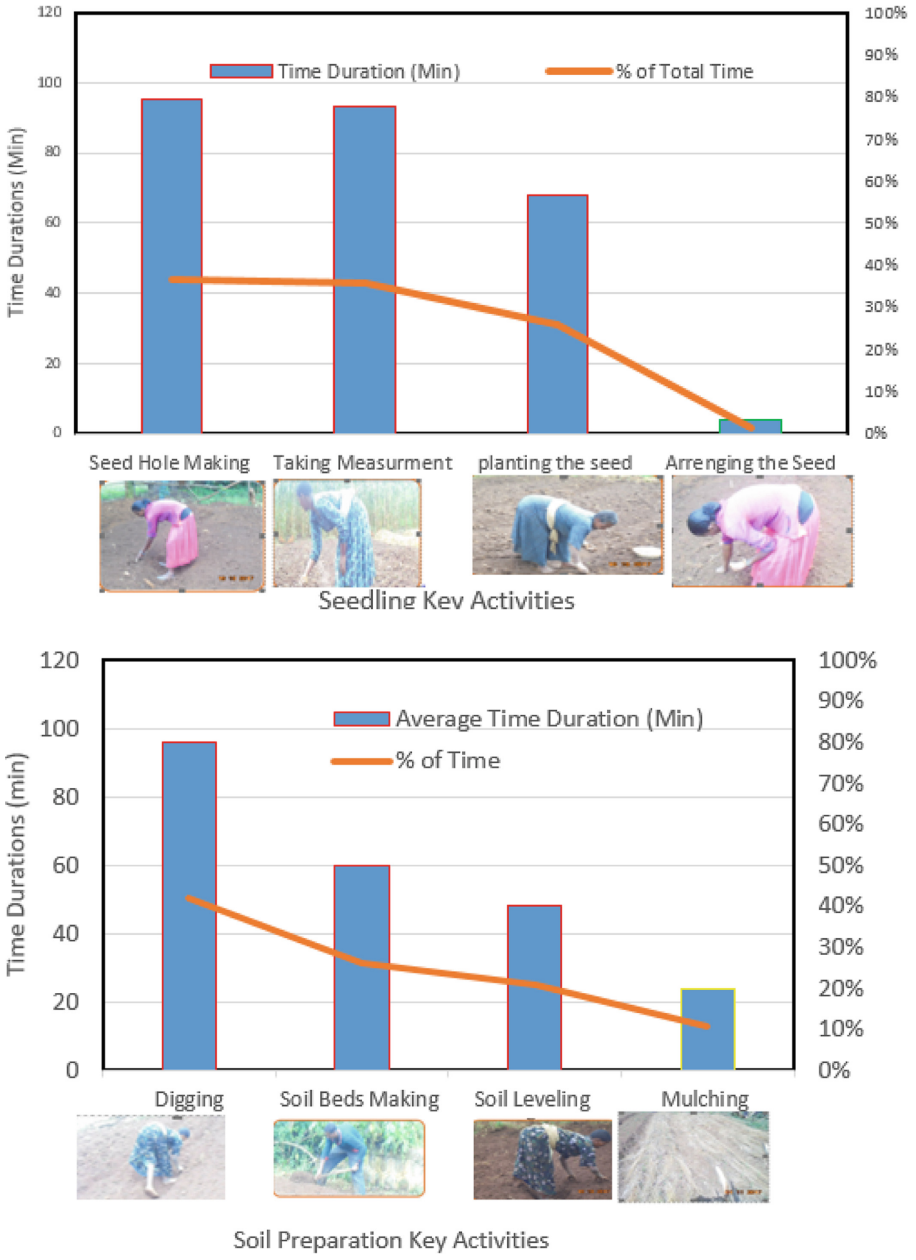

Fig. 4. Time percentage and risk estimation for soil preparation, seedling, weeding, and irrigation tasks

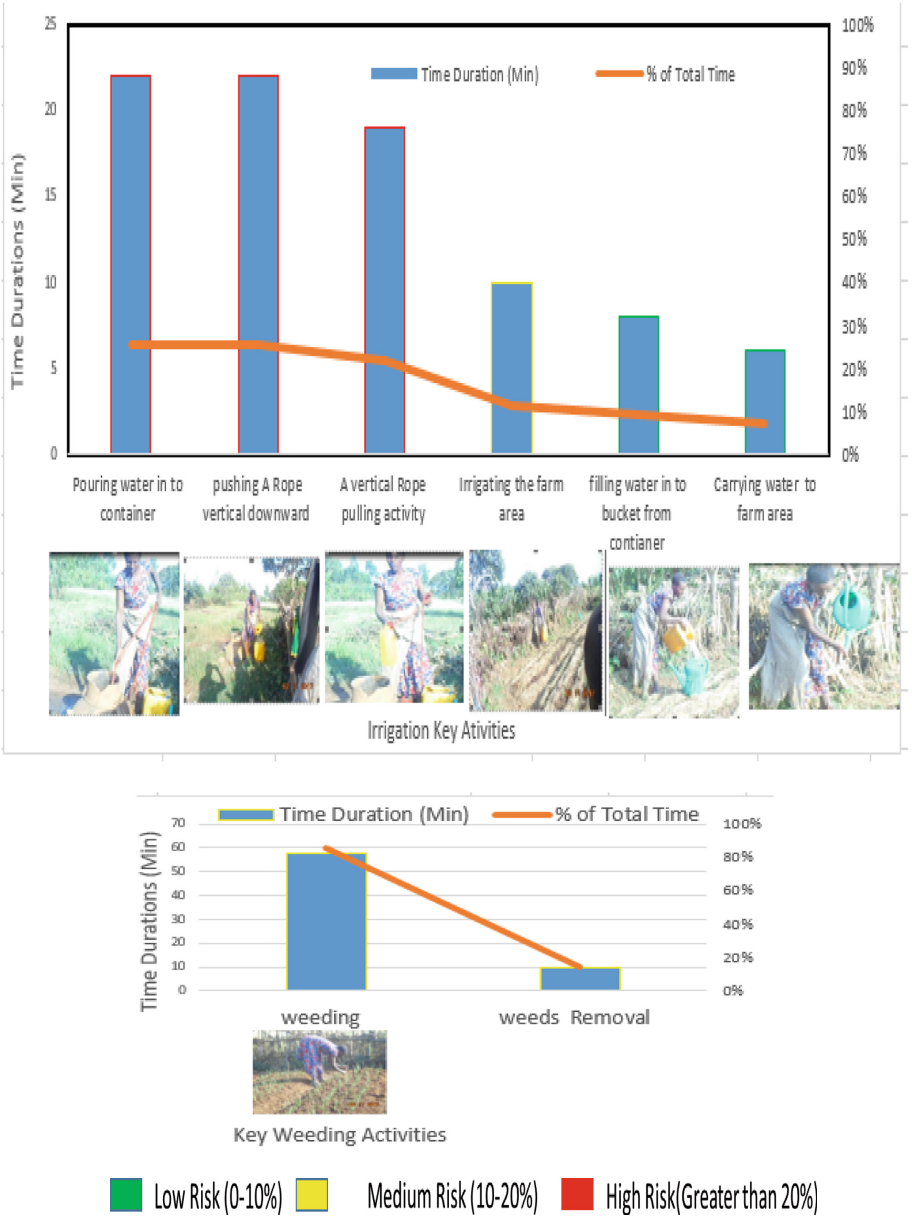

Fig. 4. (*continued*)

3.2 Ergonomic Analysis of Working Postures, Physical Effort and Time Percentage of Farming Tasks Using Videotapes

Ergonomic analysis of task considers time duration, working posture and required physical effort. Thus, in this study the ergonomic risk levels associated with dry season home

garden vegetable production process caused by these factors have been estimated using the analysis of recorded videotape of farming tasks.

Figure 4 shows the time duration, time percentages of activities and the ergonomic risk level of each farming activities from task repetitiveness point of view. The risk classification levels and their time percentages are shown below Fig. 4 as keys of the chart.

The results obtained from ergonomic analysis of working posture of women farmers, body parts such as elbow, head, neck and lower back were severe and painful work posture during performing their farming tasks as compared the standards for women work position. The farming tasks which were considered in the analysis of the work posture position included digging & soil leveling, shoveling, seedling, overhead irrigating, weeding and harvesting activities. However, the reaching work position that women farmers use during performing all farming tasks is optimal.

Recorded Videotapes of tasks were allowed to play slowly and analysis were made to identify and understand nature of activity motions. Therefore, activities motion was characterized subjectively as not visible, visible and clearly visible. The result showed that activities like digging, shoveling, water lifting, transporting, filing the bucket and irrigating demanded high physical effort and led to high ergonomic risks (Table 2).

Table 2. Ergonomic analysis of physical effort required for agricultural tasks

Tasks	Nature of the motion during performing the activity				
Soil preparation	Detail activities	Not visible	Visible	Clearly visible	Risk level
	Digging	–	–	***	High
	Moving shoveling	–	–	***	High
	Leveling	–	**	–	Medium
	Mulching	*	–	–	Low
Seedling	Measure	*	–	–	Low
	Arrange seed	*	–	–	Low
	Scratching the farm for seed hole	*	–	–	Low
	Inserting the seed	–	**	–	Medium
Irrigation	Vertical rope pulling	–	–	***	High
	Pouring water in to container	–	–	***	High
	Vertical rope pushing	–	**	–	Medium
	Water carrying to farm area	–	–	***	High

(*continued*)

Table 2. (*continued*)

Tasks	Nature of the motion during performing the activity				
	Filling water in to bucket	–	–	***	High
	Irrigating the farm	–	–	***	High
Weeding	Weeding	–	**	–	Medium
	Weeding removal	*	–	–	Low
Harvesting	Loosening the soil	*	–	–	low
	Pull garlic bulb from the soil	–	**	–	Medium
	Brushing the soil	*	–	–	Low

Note:
1. (*) Low risk level: - not visible or manipulation of light objects
2. (**) medium risk level: - visible or smooth and controlled motions; use of both hands when the task does not seem very heavy
3. (***) high risk level: - clearly visible, low control over motion, bulging muscles, facial expression, gestures, and vibration from powered hand tools

3.3 Overall Risk Level Estimation for Tasks of Home Garden Garlic Farming

Based on the risk score analysis, all farming tasks are potential to cause body part discomfort or pain. However, the severity level of the risk associated with farming activities in soil preparation and irrigation tasks were most important which demands serious measurements to be taken rapidly. One reason for the risks during performing these farming practices is due to absence of farming technologies or equipment that can support farmers to dig, seed, irrigate and harvest (Fig. 5 and Table 3).

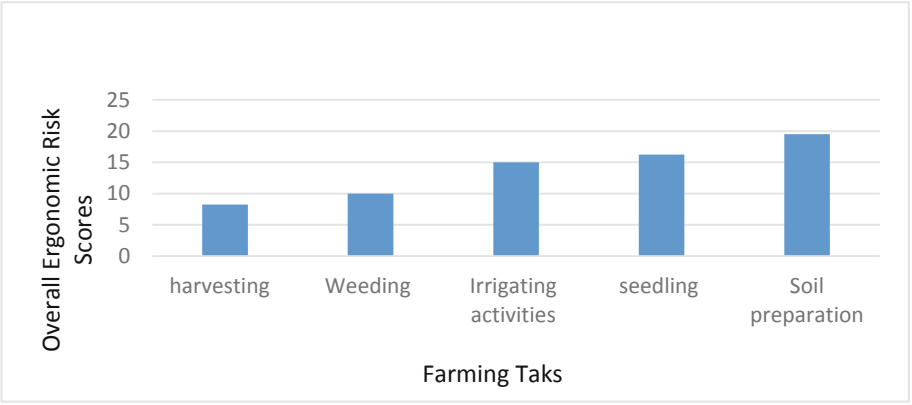

Fig. 5. Overall risk scores calculated using postural ergonomic risk assessment method

Table 3. Overall risk level estimation for each farming tasks

Task	Key activities	Force score (F)	Posture score (P)	Duration score (D)	Activity score	Overall risk score
Soil preparation	Digging	H(3)	H(3)	H(3)	27	(27 + 27 + 18 + 6)/4 = 16.25
	Shoveling	H(3)	M(2)	H(3)	18	
	Leveling	M(2)	H (3)	H(3)	18	
	Mulching	L(1)	M(2)	L(1)	2	
Seedling	Measuring	L(1)	H(3)	H(3)	9	(9 + 6+9 + 9)/4 = 8.25
	Arranging the seed	L(1)	H(3)	M(2)	6	
	Seed hole making	L(1)	H(3)	H(3)	9	
	Inserting the seed	L(1)	H(3)	H(3)	9	
Irrigation	Vertical rope pulling	H(3)	H(3)	H(3)	27	(27 + 27 + 27 + 9+27 + 18)/6 = 19.5
	Powering water in to container	H(3)	H(3)	H(3)	27	
	Vertical rope pushing	H(3)	H(3)	H(3)	27	
	Carrying water to farm area	H(3)	H(3)	L(1)	9	
	Filling water in to bucket	H(3)	H(3)	H(3)	27	
	Irrigating	H(3)	H(3)	M(2)	18	
Weeding	Weeding	M(2)	H(3)	H(3)	18	(18 + 2)/2 = 10
	Weeds removing	L(1)	L (1)	M(2)	2	
Harvesting	Loosening the soil	L(1)	L(1)	H(3)	9	(9 + 12 + 9)/3 = 15
	Pulling up garlic bulb	M(2)	H(3)	M(2)	12	
	Brushing the soil	L(1)	H(3)	L(1)	9	

4 Conclusion

Production of vegetable such as garlic at home garden during dry period included various agricultural tasks such as preparing the land or soil, seedling or planting of the seed, periodical irrigating of the farm, weeding activities, harvesting activities and transporting the farm yields to home and then market. Based on the survey of women farmers, lower back, elbow, shoulder, wrist or hand, neck and knee are most affected body parts of the women during the dry period vegetable production. The case showed that highest number (100%) of the respondents informed they perceived discomfort or pain at the lower back of their body part and minimum number (38%) of respondents informed they perceived pain at their hips. From the study of ergonomic analysis, we concluded that the severity level of the risk associated with farming activities were sever in soil preparation and irrigation tasks. The possible intervention to reduce these sever risk are adoption of conservation agriculture i.e., no till, mulching and crop rotation, adopting and use of ergonomic tools and equipment that can support soil preparation, adopt and use of water lifting technologies with drip irrigation system and redesigning of farming hand tools.

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References

U.S. Department of Labor Occupational Safety and Health Administration: Ergonomics: the study of work, OSHA 3125 revised (2000)

Divyaksh, S., Maria, P.: An observational method for postural ergonomic risk assessment (PERA). Int. J. Ergon. **57**, 32–41 (2017)

Kai, W.: Ergonomic design and evaluation of wire-tying hand tools. Int. J. Ind. Ergon. **30**, 149–161 (2002)

Putz, A.: Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs. Taylor & Francis, London (1988)

Karla, G., Juan, L., Gabriel, I.: A proposed methodology for task analysis in ergonomic evaluations. Procedia Manuf. **3**, 4756–4760 (2015). 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Lane, R., Stanton, A., Harrison, D.: Applying hierarchical task analysis to medication administration errors. Appl. Ergon. **37**, 669–769 (2006)

Robertoes, K., Wibowoa, P.: Farmers'Injuries, discomfort and its use in design of agricultural hand tools: a case study from East Java. Indonesia. Agric. Agric. Sci. Procedia **9**, 323–327 (2016). International Conference on Food, Agriculture and Natural Resources, IC-FANRes 2015. Elsevier B.V

Tahseen, J., David, H.: The application of ergonomics in rural development: a review. Appl. Ergon. **31**(3), 263–268 (2000)

Holmer, I., Takala, J., Chavalitnitikul, C.: Implementation of ergonomics in Thailand. In: Ergonomics in Developing Countries. An International Symposium. International Labor Organization (ILO), Occupational Health and Safety Series, ILO, Geneva, no. 58, p. 502 (1985)

Barenklau, K.: Agricultural Safety. CRC Press, Boca Raton (2001)

André, L., Gilberto, J., Airton, D., Aimê, R.: Ergonomics applied to aquaculture: a case study of postural risk analysis in the manual harvesting of cultivated mussels. Aquac. Eng. **77**, 112–124 (2017)

Steven, M., Arun, G.: The strain index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am. Ind. Hyg. Assoc. J. **56**, 443–458 (1995)

Liu, C., Zhang, X., Zhang, Y.: Determination of daily evaporation and evapotranspiration of winter wheat and maize by large-scale weighing lysimeter and microlysimeter. Agric. Forest Meteorol. **111**, 109–120 (2002)

Monks, D., Monks, D., Basden, T., Selders, A., Poland, S., Rayburn, E.: Soil temperature, soil moisture, weed control, and tomato (Lycopersicon esculentum) response to mulching. Weed Technol. **11**, 561–566 (1997)

Surabhi, S., Renu, A.: Ergonomic intervention for preventing musculoskeletal disorders among farm women. J. Agric. Sci. **1**, 61–71 (2017)

Hassan, S., Karmegam, K., Shamsul, B., Koustuv, D.: Ergonomics in agriculture: an approach in prevention of work-related musculoskeletal disorders (WMSDs). J. Agric. Environ. Sci. **2**(3), 33–51 (2014)

Villarejo, D., Baron, S.: The occupational health status of hired farm workers. Occup. Med. State Art Rev. **114**(3), 613–635 (1999)

Praveena, P., Achuta, R., Venkata, R.: Decision making pattern of rural women in farm related activities. Agric. Extn. Rev. **3**, 3–7 (2005)

Meyers, J., et al.: Ergonomics risk factors for musculoskeletal disorder in wine grape vineyard work. Paper presented at the National Institute for Farm Safety, Winnepeg, Canada (1998)

Engberg, L.: Women and agricultural work. Occup. Med. **8**, 869–883 (1993)

Falkel, J., Sawka, N., Levine, L., Pimental, N., Pandolf, K.: Upper-body exercise performance: comparison between women and men. Ergonomics **29**, 145–154 (1986)

Mackay, D., Bishop, C.: Occupational health of women at work: Some human factors considerations. Ergonomics **27**, 489–498 (1984)

FAO: Agricultural Mechanization in Sub-Saharan Africa Guidelines for preparing a strategy, vol. 22. Rome (2013)

Mekuria, W.: The link between agricultural production and population dynamics in Ethiopia: a review. Adv. Plants Agric. Res. **8**(2), 348–353 (2018). https://doi.org/10.15406/apar.2018.08.00336

Palacios-lopez, A., Christiaensen, L., Kilic, T.: How much of the labor in African agriculture is provided by women? Food Policy **67**, 52–63 (2017). https://doi.org/10.1016/j.foodpol.2016.09.017

Endalew, B., Muche, M., Tadesse, S.: Assessment of food security situation in Ethiopia: a review. Asian J. Agric. Res. **9**, 55–68 (2015)

Amare, D., Endalew, W.: Agricultural mechanization: assessment of mechanization impact experiences on the rural population and the implications for Ethiopian smallholders. Eng. Appl. Sci. **1**(2), 39–48 (2016). https://doi.org/10.11648/j.eas.20160102.15