A Mobile Based Decision Support System for Postural Evaluation of Agricultural Activities with Rapid Entire Body Assessment (REBA)

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1. INTRODUCTION

In India, a large number of human resources is mainly associated with agricultural work which demands human energy. Agricultural workers agonize from musculoskeletal disorders in different body parts during different agricultural activities (Ojha *et al.*, 2017). Farmworkers carry out a fair amount of manual, continuous meticulous tasks in the field. Agriculture is one of the most dangerous fields of work requiring labor-intensive operations and, in many countries, it shows high levels of musculoskeletal disorders (MSDs). The causes of MSDs in agriculture are the result of heavy pressure, constant motion, uncomfortable working postures, a long time working in sitting conditions, and the use of conventional tools and implements that are not ergonomically built (Joshi *et al.*, 2014). Different types of work-related MSDs are described among women. These include disorders of the back and neck, nerve entrapment syndromes, musculoskeletal disorders such as tenosynovitis, tendinitis, peri-tendinitis, epicondylitis, and nonspecific muscle and forearm tenderness (Devi *et al.*, 2019). The majority of the farm women reported musculoskeletal problems is non-specific and lacks a well-defined clinical diagnosis. The prevalence of specific disorders and syndromes are not precisely known since many of these disorders have been difficult to classify in epidemiologic studies (Halim *et al.*, 2014). Various evaluation devices used to measure the ergonomic threat elements intricate in the working environment for assessing the capacities and limitations of the worker. The evaluation tools like Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA; mentioned in Abhishek *et al.*, 2019) used to measure the work related risks. Ergonomics studies reports spinal loading during manual load carrying which results in degeneration of the disc and musculoskeletal disorder (Kuiper *et al.*, 1999). Accelerated cervical spondylitis is also reported as a result of carrying load on head (Joosab *et al*., 1994; Jager *et al.*, 1997). Boocock *et al.*, (1994) reported that work activities which requires posture in which lumber region is extended (overhead work) are relatively common, may induce compressive loads of biomechanical hazards.

REBA is a postural assessment technique that provides a quick and easy measure to assess a variety of working postures for the risk of WMSD's. The REBA technique used to measure different work-related postures of agricultural operations and risk factors of musculoskeletal disorder where the entire body is involved in doing work. It divides the body into sections to be coded independently, according to movement planes and offers a scoring system for muscle activity throughout the entire body idle, dynamically, fast changing or in an unsteady way and where manual handling may happen which is referred to as a coupling score as it is significant in the loads handling but may not always be using the hands. REBA score explains the severity of MSD experienced by operators who work under certain conditions.

With the fast-technological improvement, the propagation of the internet, and globalization, the role of technology has changed from supporting corporations to transforming them. The Digital India agenda is a flagship schedule of the Government of India with a dream to change India into a digitally empowered society and knowledge economy. We will revitalize and revamp the extension programs in such a way that they can more effectively reach the farmers. The evolution of the "Decision Support System for Postural Assessment of Agricultural Activities with Rapid Entire Body Assessment (REBA) Technique" is an effort in this direction.

For more than 40 years in agriculture and related fields computers have been used. The fields of use of this system have grown from many current applications of agricultural research such as control, assessment and information processing, education and training programs, broadcasting, and support for decision making. Owing to the possibility of data collection and dissemination, the use of computers has improved the knowledge as well as the capacity of various departments (Sharda *et al.,* 1988). The recent advancements in computing and communication technologies have made use of software and hardware much simpler have been allowed the flow of information use quicker. Decision Support System (DSS) is a synergistic tool that provides computer-based modelling structure and expertise to support conclusion making processes, helps clarify the problem, explores various possible action paths, their impacts and promote sensitivity analysis. A mobile application is a kind of application software intended to run on a mobile phone. They are by and large small, individual software units with restricted capacity and can be downloaded easily on mobile phones for using them anytime, anywhere. They often serve to furnish clients with data, information and knowledge related to a specific area. A DSS for postural assessment of agricultural activities with REBA is a mobile application which will be helpful for physiological and postural assessment of persons involved continuously in physical work such as agricultural activities. It will provide recommendation of correct posture to avoid developing musculoskeletal disorders.

2. MATERIALS AND METHODS

Different software and tools that are used to develop the proposed DSS are JAVA programming language, XML, Android Platforms, DB Browser to design, create and edit database files with the SQLite, JAVA Libraries, Android Studio IDE used to develop the Android app, SQLite is the open source relational database used to store data on the device in the form of text files and Android Virtual Device (AVD) tool. In the project Android Studio version 3.6 with JDK version 1.8 is used for the development of the app.

2.1 System Architecture

The Mobile based DSS for Evaluation of Postural Ergonomics using REBA (MDSS-REBA) is developed on Android platform. The MDSS is connected to the SQLite which provides database service for data storage and web related services.

The Android based DSS is composed of more than one component written in Java classes. Communications allying the application and SQLite is shown in Figure 1 and the information flow of the system is shown in Figure 2 as follows:

- There are two parts in the Architecture of the App, in the first part there is a physiological analysis, and in the second part, there is a postural analysis.
- In the preliminary stage of development of the DSS, the table data has been stored in the SQLite in the background.

- After completion of database storage, useful data is retrieved from the SQLite.

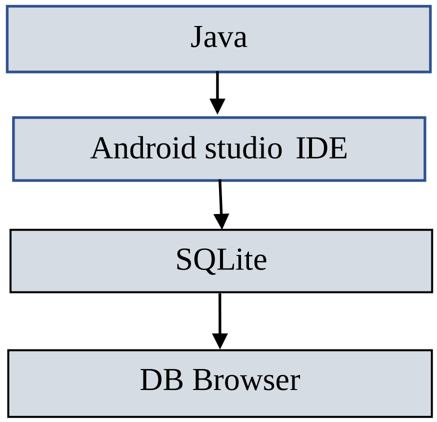

Fig 1: Architecture of Mobile based DSS '*REBA*'

The research work analysis of the farmers and their farm work has been conducted on the basis of physiological and psychological ergonomics parameters, viz. Body Mass Index, Physical Fitness Index, Energy Expenditure Rate (EER), Total Cardiac Cost of Work (TCCW), Physiological Cost of Work (PCW) and Human Physical Drudgery Index (HPDI). First of all, the health condition of the farmers is evaluated using Body Mass Index (BMI) and Physical Fitness Index (PFI). If result of both the parameters come in suitable range then only we will proceed further towards EER, TCCW, PCW and HPDI analysis.

The Body Mass Index defines whether the weight of the farmer is justified with his height or not. Following formula is used to calculate BMI:

$$BMI= Weight\ (kg)/Height^2\ (m) \text{ ----------(1)}$$

The PFI denotes the health condition of the farmer. It is calculated by doing a work for 5 minutes and then recording the heart rates at three different times of recovery. The following formula is used to calculate PFI.

$$PFI= (\text{Duration of activity}/ (\text{sum of I, II and III minutes of recovery of HR})) * 100 \text{ -------(2)}$$

$$\text{Energy Expenditure Rate (EER)} = 0.159 \times \text{heart Rate (b/min)} - 8.72 \text{ ------------(3)}$$

Circulatory stress was evaluated from the cardiac cost of work and cardiac cost of recovery. The cardiac cost of recovery is the total number of heart beats above the resting level occurring between the end of the work and return to the resting state.

Following formulae were used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW) (Singh *et al.* 2008).

$$CCW = \Delta\ HR.\ tA \text{ ---------(4)}$$

where, CCW=Cardiac Cost of Work ΔHR=Mean Working heart Rate – Mean Resting heart Rate tA = Duration of Activity.

$$CCR = (AhR\ recovery - AhR\ rest).\ tR \qquad \text{---------(5)}$$

where, CCR = Cardiac Cost of Work AhR recovery = Average Recovery heart Rate,

AhR rest = Average Resting heart Rate, tR = Duration of Recovery.

$$TCCW = CCW + CCR \text{ ------(6)}$$

Where, TCCW = Total Cardiac Cost of Work.

$$PCW = TCCW/tA \quad \text{-------(7)}$$

Where, PCW = Physiological Cost of Work.

The worksheet of REBA shown in Figure 3 and postural work flow analysis shown in Figure 4 is portioned into different body segments and named as A and B. The Left side segment A encloses the Neck, Trunk, and Leg analysis. The right side segment B encloses the Arm and Wrist analysis. Segmentation in the worksheet certifies that any difficulty or forced postures of the Neck, Trunk, and Legs which might affect the postures of the Arms and Wrist are involved in the analysis. First Group A score (Neck, Trunk, and Legs) postures, then Group B score (Upper Arms, Lower Arms, and Wrists) postures for left and right. There is a posture scoring scale for each region, and additional adjustments needed to be examined and considered for in the score.

The workflow of REBA application is depicted in Figure 2 and the work flow of postural analysis using DSS is depicted in Figure 3.

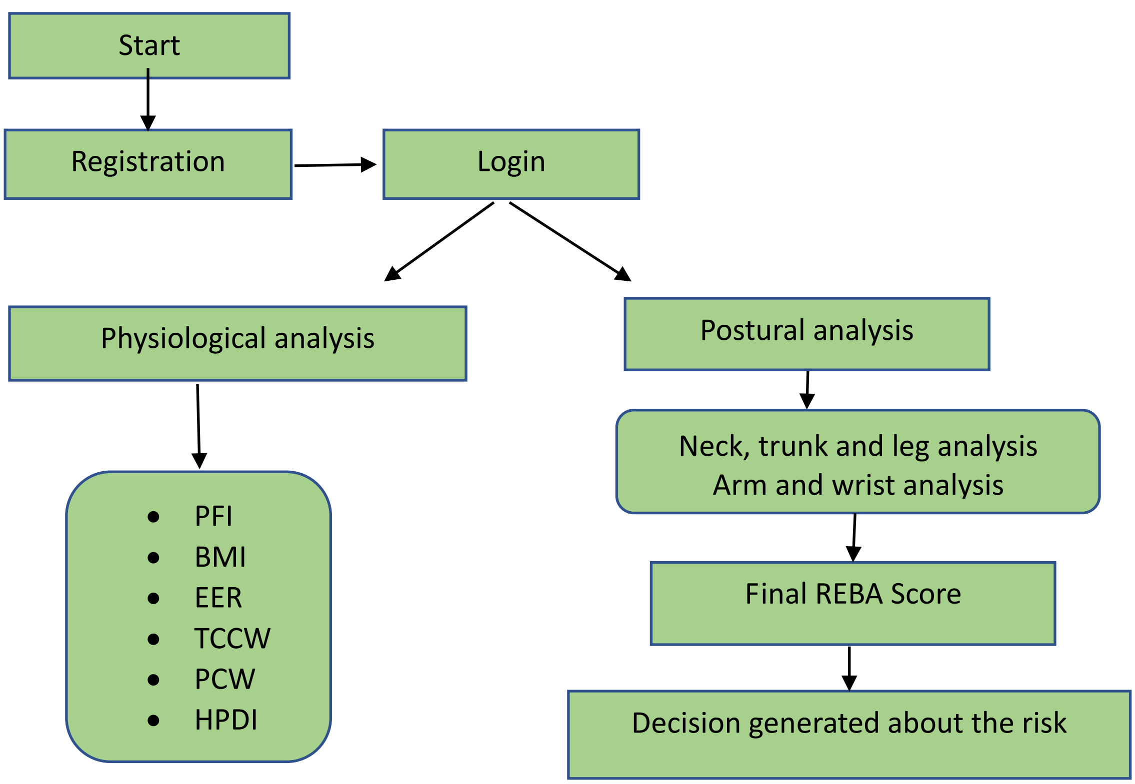

Fig 2: **Work flow of REBA Mobile application**

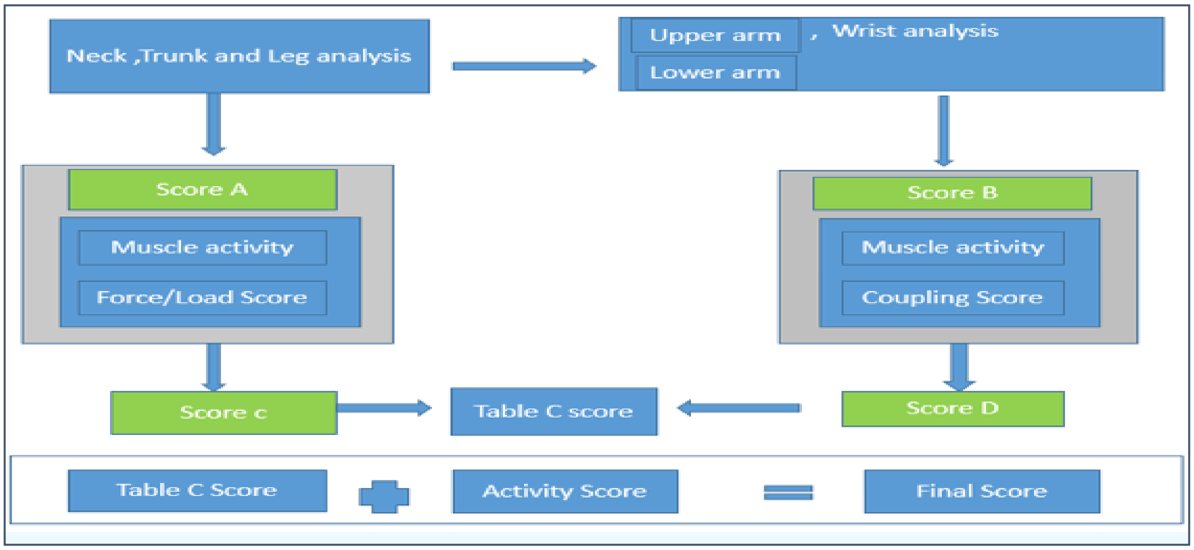

Fig 3: Work flow of Postural analysis using DSS

3. RESULTS AND DISCUSSION

An android based mobile app has been developed under the study which supports decision making regarding the extent of drudgery involved and desired course of action for the agricultural activity performed. The main aim of the application is to evaluate the various agricultural activities based on the different ergonomic parameters and suggest correct postures. The app "***REBA***" has been successfully developed for postural ergonomics for the activities where upper and lower body extremities are used simultaneously such as transplanting, load carrying etc. The mobile based decision support system is developed for analysing the drudgery that is involved in the various agricultural activities performed by the farmers as a part of crop production practices using the rapid entire body assessment technique to provide a decision regarding the extent of drudgery involved and desired course of action in the performed activity. The application is tested on sample data.

Users can use the *REBA* application only after the successful registration. Registration requires some information, by providing those requirements users can register to the app as shown in Figure 4. After user registration there is an option for registering the details for each farmer on whom we can perform the drudgery analysis. There are two options available to the user. One is if the user is new then he or she don't have any farmer registered under him or her. So he or she must have to register the details of the farmer on whom he or she wants to perform biomechanical analysis. In that case the user has to click on the button "Register New farmer". Then the user has to enter the name, age, village, district and state of the farmer. There will be a list of farmer will be shown on the screen who are registered under that particular user. We can proceed further by selecting the desired farmer. If the user who is an old user wants to show the farmer list which was made by him or her and also wants to perform the Biomechanical and drudgery analysis on those previously registered farmers. For executing this requirement, the button “Show Existing Farmer” is used and similarly we can proceed by selecting one farmer from the list.

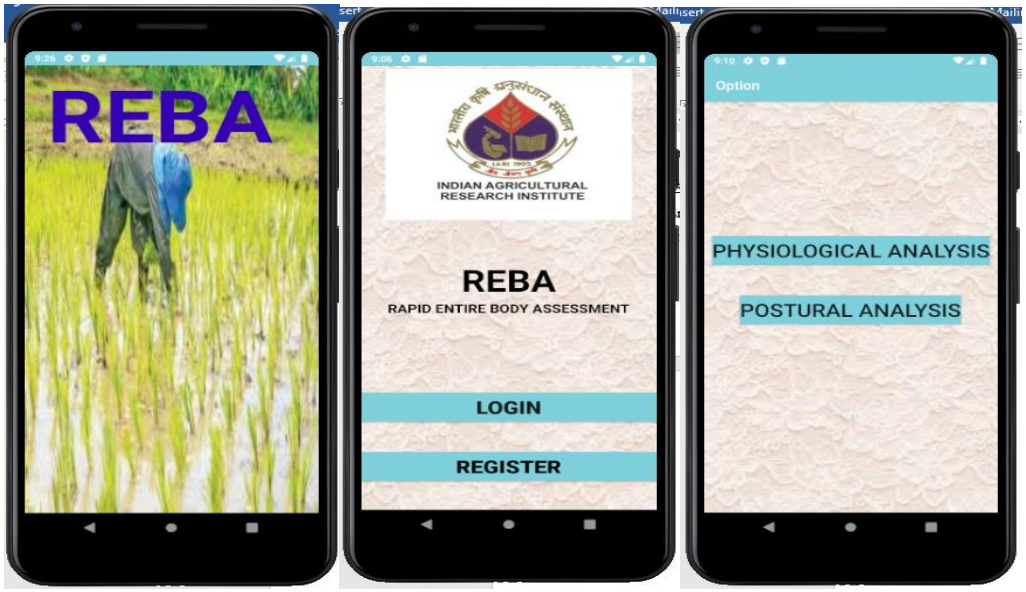

Fig 4: Estimation of drudgery using REBA

3.1 Physiological analysis

For BMI analysis the farmer’s height and weight is entered and the farmer is evaluated by comparing the obtained value with the range wise category of BMI as shown in Figure 5. The DSS will infer whether the farmer is suitable for further assessment. The calculated BMI, the entered height and weight are also stored in the database.

For PFI first of all the farmers whom we want to evaluate is to be selected and allowed to do an activity for 5 minutes or 300 seconds. After that the required inputs which are the three heart rates at 1st, 2nd and 3rd minute of recovery are entered and the PFI value is calculated by clicking on the “Submit” button. By comparing the obtained PFI value with the range of PFI values screen the selected farmer is evaluated.
The Energy Expenditure Rate (EER) is calculated based upon the value of heart rate in working condition. Besides the EER the circulatory stress experienced by the agricultural workers during working can also be calculated using Cardiac Cost of Work (CCW) and Cardiac Cost of Recovery (CCR). The TCCW and PCW is calculated using the DSS where TCCW is dependent upon CCW and CCR and PCW is evaluated using TCCW and Duration of Work.

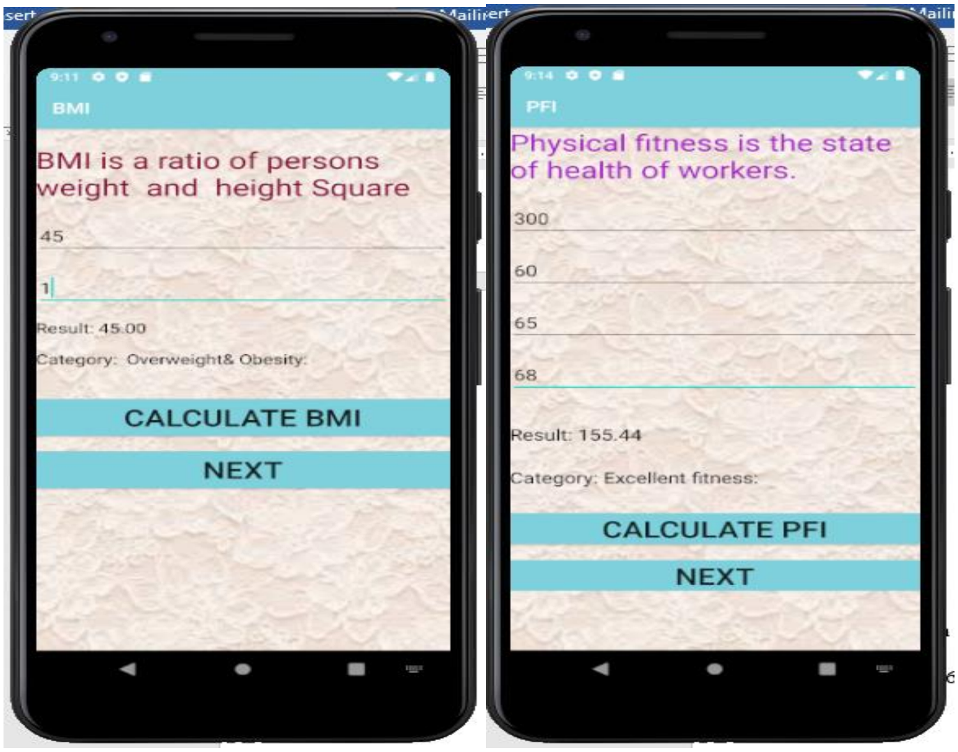

Fig 5: Physiological analysis

3.2 Postural analysis

3.2.1 Neck Analysis

Evaluation of the Neck posture is based on the degree of neck flexion or extension, as well as any correction for neck twisting or side bending (lateral flexion) as shown in Figure 6.

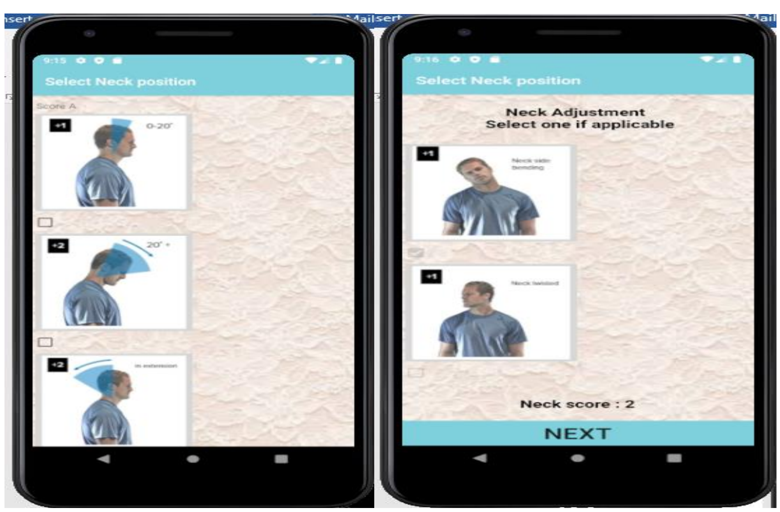

Fig. 6: Neck analysis

3.2.2 Trunk Analysis

Evaluation of the Trunk is based on the degree of trunk flexion or extension, as well as any correction for trunk twisting or side bending (lateral flexion) as shown in Figure 7.

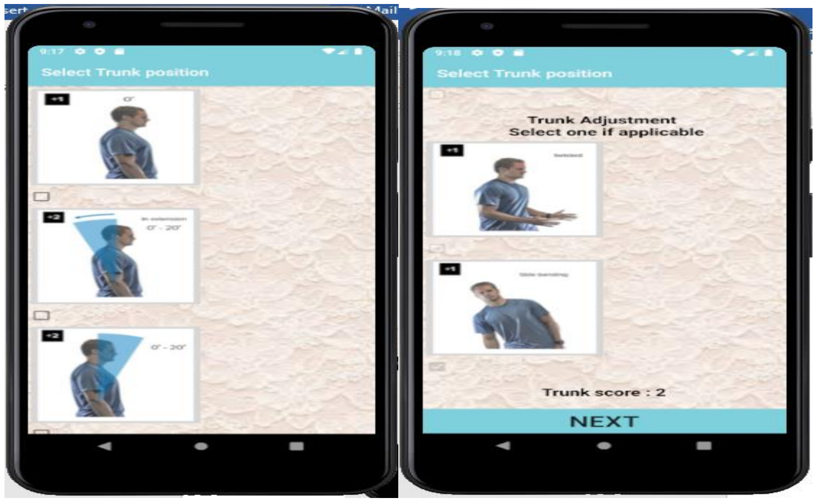

Fig. 7: Trunk Analysis

3.2.3 Leg Analysis

Evaluation of the Leg is based on the bilateral or unilateral weight bearing on the legs, as well as any correction for knee. Knee flexion is the bending angle between the femur and tibia bones of the limb at the knee joint and also score A (Neck, Trunk, Leg analysis) is calculated as shown in Figure 8.

Fig. 8: Leg analysis

3.2.4 Arm analysis

Evaluation of the Arm is based on the degree of shoulder flexion or extension, along with an adjustment for the raised shoulder as shown in Figure 9.

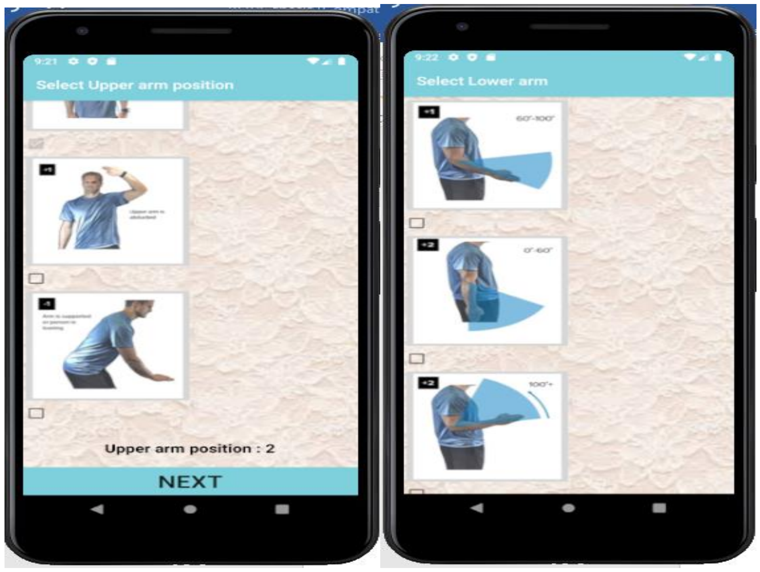

Fig. 9: Arm assessment

3.2.5 Wrist analysis

Evaluation of the Wrist is based on the degree of wrist flexion or extension, as well as any correction for wrist deviation or twisting and score B (Arm and wrist analysis) is calculated as shown in Figure 10, 11.

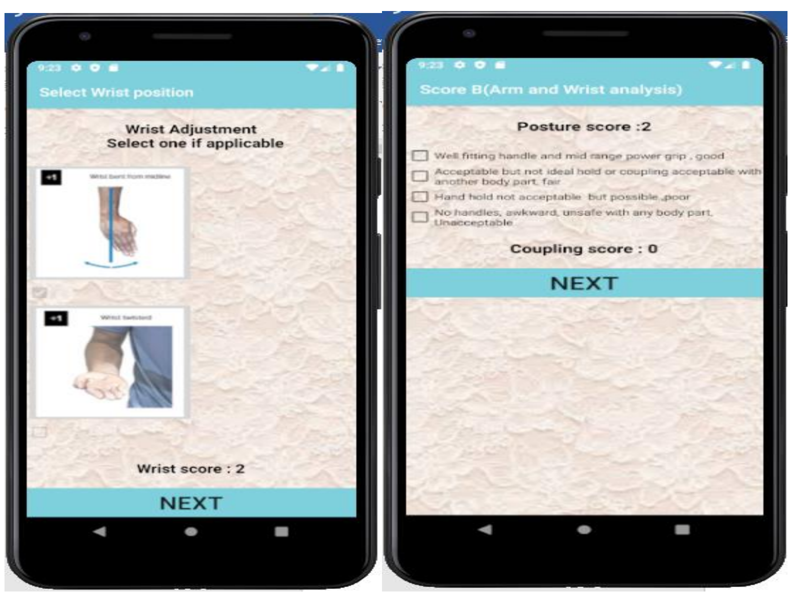

Fig.10: Wrist analysis

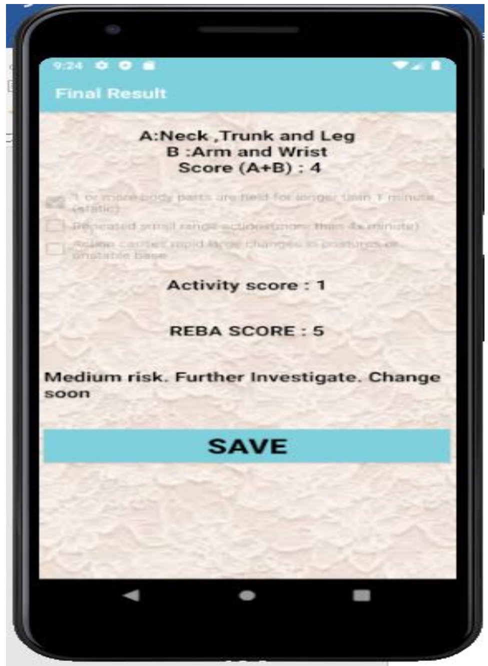

Fig. 11: Final REBA score

REBA Score pertaining to activities are given in Figure 12, with level of Musculoskeletal risk and recommendation for future course of action. The characterization of score refers to score 1 (negligible risk, no action required), score 2-3 (low risk, change may be needed), score 4-7 (medium risk, further investigation, change soon), score 8-10 (high risk, investigating and implement change) and score 11 or more (very high risk and implement change).

Score	Level of MSD risk
1	Negligible risk, no action required
2-3	Low risk, change may be needed
4-7	Medium risk, further investigation, change soon
8-10	High risk, investigating and implement change
11+	Very high risk, implement change

Fig. 12: Level of MSD risk

4. CONCLUSION

The Mobile based decision support system for assessing working posture and physiological analysis during agricultural activities is developed to avoid the musculoskeletal disorders of rural workers and improve health. DSS performs various calculations, access data from the database stored in tables, and provides results, reports and recommendations. The developed MDSS-REBA has been tested and validated using the sample data for physiological and postural assessment of Musculoskeletal disorders (MSDs). The system provided accurate results which were verified by the evaluators. It is helpful for finding the drudgery prone activities in agriculture. It also helps to identify the part of activity which is causing the drudgery and therefore reducing it by adopting new tools or by changing the traditional method of cultural practices. The application will interact with the database internally in order to access as well as store data from the database. The results discuss the output of the research and also explains the flow of DSS. It displays the decision support system interface that connects with the end user straight away. The target beneficiaries of the mobile application are researchers, agricultural engineers, developers and evaluators of farm tools and machineries on ergonomics protocol.

REFERENCES

Abhishek, M. P., Kumar, M., Joshi, P., Dahiya, S., Arora, A. and Pal, S. (2019). Development and validation of mobile based decision support system for postural assessment of agricultural activities using rapid upper limb assessment (RULA) technique. Progressive Research. 14: 335-337.

Boocock, M. G., Jackson, J. A., Burton, A. K. and Tillotson, K.M. (1994). Continuous measurement of lumber spinal posture using flexible electrogonionmeters. *Ergonomics,* 37: 175-85.

Devi, G. N., Mallikarjun, M., Reddy, P. N. and Kumar, M. R. (2019). Ergonomic Study on Drudgery Reduction Using Easy Planter for Transplanting Tomato Seedlings. *Int. J. Curr. Microbiol. App. Sci*, 8(7): 2499-2506.

Halim, I., Arep, H., Kamat, S. R., Abdullah, R., Omar, A. R. and Ismail, A. R. (2014). Development of a decision support system for analysis and solutions of prolonged standing in the workplace. *Safety and Health at Work*, 5(2): 97-105.

Hignett, S. and McAtamney, L. (2000). Rapid entire body assessment (REBA). *Applied Ergonomics*, *31*(2): 201-205.

Jager, M. and Luttmann, A. (1999). The load on the lumbar spine during asymmetrical bi-manual materials handling. *Ergonomics*, 35: 783-805.

Joosab, M., Torode, M. and Rao, P.V. (1994). Preliminary findings on the effect of load carrying to the structural integrity of the cervical spine. *Surgical and Radiologic Anatomy,* 16(4): 393-398.

Joshi, P., Jethi, R., Chandra, N., Roy, M. L., Kharbikar, H. L. and Atheequlla, G. A. (2016). Ergonomics Assessment of Post Harvest Finger Millet Threshing for reducing Women Drudgery. *Indian Research Journal of Extension Education*, 15(1): 25-30.

Khayer, S. M., Patel, T. and Ningthoujam, B. (2019). Ergonomic Postural and Biomechanical Analysis of Manual Weeding Operation in Agriculture Using Digital Human Models. Springer, Singapore in *Research into Design for a Connected World* 41**:**451-62.

Kuiper, J.I., Burdorf, A., Verbeek, J. H. et al. (1999). Epidemiologic evidence on manual materials handling as a risk factor for back disorders: a systematic review. *International Journal of Industrial Ergonomics*, 24: 389–404.

Ojha P, Poonam S, and Abha S. 2017. Assessment of drudgery level of female farm workers involved in sugarcane cultivation. *Asian Journal of Home Science*. 12(1): 205-7.

Sharda R, Barr S H and McDonnell J C. 1988. Decision support system effectiveness: a review and an empirical test. *Management science*. 34(2): 139-59.

Singh S P, Gite L P, Majumder J and Agarwal N. 2008. Aerobic capacity of farmwomen using sub-maximal exercise technique on tread mill. *Agricultural Engineering International: the CIGR EJournal*. Manuscript MES 08 (10): 1-10.

Mallick, P. (2016). Mobile Application for Plant Quarantine Regulations to Import in India. M.Sc. Thesis Dissertation, IASRI, New Delhi.

Priyadarshini, S. (2016). Mobile App for Chlorophyll Content Estimation in Rice. M.Sc. Thesis Dissertation, IASRI, New Delhi.

Pal, A., De, S., Sengupta, P., Maity, P., & Dhara, P. C. (2015). Evaluation of work related musculoskeletal disorder and postural stress among female potato cultivators in West Bengal, India. *Ergonomics SA: Journal of the Ergonomics Society of South Africa*, *27*(1), 46-64.

Sung, K., & Freivalds, A. (2014)). Evaluating both Physiological and Biomechanical Strains in Women Using Different Hoe Handle Designs. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 58, No. 1, pp. 1795-1799). Sage CA: Los Angeles, CA: SAGE Publications.

Sonkusle, L. (2018). Mobile App for Ergonomics assessment of Drudgery prone activities in agriculture (master's thesis). Indian Agricultural Statistics Research Institute, IARI, New Delhi.

Tutorial, XML (2006). W3Schools. Available at: http://www.w3schools. Com/xml /default.asp.

Vasudevan, S. and Misra, K. D. (2016). Sourcebook on Drudgery Reduction Technologies for Women in Rural Areas. Vigyan Prasar, 25-95.