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A Postural Risk Assessment of Manual Dairy Farm Workers using NIOSH Lifting Equation

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Abstract: The postural risk assessment plays a very important role in calculation of musculoskeletal fatigue in human beings. A study in similar contrast contributes to an enhanced intellect of NIOSH Lifting Equation in consideration to the weight lifting conditions of manual dairy farm workers through an exhaustive description of the process involved in measuring variables affecting the risk score of an individual. NIOSH Lifting Equation is an Ergonomic technique with a systematic approach to calculate the risk score of workers involved in frequent and heavy load lifting tasks. A data driven approach capturing both films and photographs was used for evaluation along with measurement tools to calculate risk score from initial to final point of loading. The evaluation resulted in Recommended Weight Limit (RWL) of 27.86 Kgs and Lifting Index (Li) of 1.23. A trained analyst helped handling the device and also the calculation of lifting index (Li) in dairy farm area. A revised form of NIOSH Lifting equation with systematic and reliable procedures resulted in modifications in design of workstations that involved frequent load lifting for workers in dairy farm, thereby reducing the musculoskeletal disorders.

Keywords: Musculoskeletal disorders, NIOSH equation , Dairy farming, Occupational safety

1. Introduction

In year 1962, the load limits for manual work were defined by International Labor Organization, as reported by Chaffin[2]. The limits were recognized based on the study conducted by an expert panel of medical team.

The limits were defined considering the dimensions and frequency of objects to be lifted. But after a certain span of time, the permissible limits lack due to a prominence of injuries resulting out of musculoskeletal disorders. A revised document for best practices related to lower back injuries and musculoskeletal disorders was been published in year 1981 by the US National Institute for Occupational Safety and Health (NIOSH) for Manual Lifting tasks, as also shown in NIOSH, 1981[10] .

The occupational health is always of great importance and there has always been a continuous development by industry in every sector to focus on human safety and eradicate all kind of health hazards using best of research and latest technology. With the development of new industrial era, occupational health and safety is a subject of concern for every sector, may be related to agriculture, machinery, construction, packaging, healthcare etc. For every business, the occupational accidents or illness is a big disaster resulting in direct and indirect cost for employers. It may be grant of compensatory benefits, halt in production, poor quality of work, more administrative costs, cost incurred in maintenance and repair of machinery, idle machine time and above all a negative morale of employees. An balanced physical, social and mental well being of employees is an important aspect for an efficient working of an organization.

The study on Padang earthquake shows the relation between increasing operational cost and carrying or transportation cost with respect to the increasing count of health workers and the set up cost for cure of human labour in industry[16]. Similarly, a study in Indonesia polyclinic waiting room used a quantitative descriptive approach to define suitable standards of air flow quality and few other variables mandatory for natural ventilation required for healthy well being of workers in their occupation[17]. A study on highway maintenance system focussed on safety of workers by introducing a signal warning detector system which sent emergency light and a signal siren to avoid accidents in emergency lane for

fast and rash driving. Occupational health is given importance in every industry[18]. The paper highlights that earlier the health hazards were feared as global risks like after-effects of armed rebellions, nuclear wars but after coronavirus impact the industries have transformed with more focus towards improving health conditions of employees and using innovative technology to eradicate occupational health issues[19]. An investigation in Thailand by Tungjiratthitikan about industry accidents happened in past 17 years shows that hazards arise due to lack of proper training and educational programs and the limitation of skill and understanding of operations[20].

The study on routine occupational tasks by workers in various occupations show their involvement in continuous rigorous activities which result in severe health hazards thereby even reducing their life span and generating stress throughout the body by Gurnani et. al[21]. The paper investigates on occupational health issues faced in construction industry due to frequent load lifting and the effect on muscular movements due to such lifting activities and the ergonomic intervention to resolve these health hazards by Bairwa et. al[22]. Another focus on health hazards is on respiratory disorders in small scale wood and stone cutting industry developed due to continuous inhalation of dust and fumes and the study also reveals further scope of improvement in this industry keeping necessary precautions by Yogesh et.al [23]. The author reveals that occupational health hazards are even prominent in simple work like agriculture with most prevalent musculoskeletal disorders due to repetitive working in awkward postures and other health issues arising due to exposure to machine vibrations and hot weather conditions[24]. The author shows a study on effect of tools and accessories used for better gripping and safety in industry. The type of material and design of hand tools with ergonomic intervention impacts the safety and reduces and accidental risks within the industry while working on any machine[25].

The ergonomic intervention in different industries is influenced by the different techniques used for assessment of musculoskeletal disorders like REBA, RULA, OWAS, NIOSH, WISHA. Every technique used by researchers in different sectors over different occupational activities result a assessment score to define the risk level of an individual. Various direct measurement tools like motion capture machine, goniometer, push/pull force sensors are used widely for observational methods. Rapid Upper Limb Assessment (RULA) is used for a quantifying exposure in upper part of body including trunk, neck, upper limbs whereas Rapid Entire Body Assessment (REBA) is used for full body screening with a systematic process to study the biomechanical and postural loading on the body. OWAS (Ovako Working Posture Analysis System) is used to identify unsafe work postures causing injuries and lower back pain due to the frequency and duration of the task. National Institute for Occupational Safety and Health (NIOSH) equation defines the acceptable limit of weight suitable for a worker to be lifted for a shift of 8 hours.

The author investigates the comparative analysis of risk scores developed in blue collar job workers in a university involved in lifting and material handling operations at workplace. A comparative study on assessment of risk scores using ergonomic tools of REBA, RULA, NIOSH and WISHA illustrates that in most of the lifting operations 30% of work activities are categorized under high risk, 45% in medium risk and remaining in low risk zone. NIOSH was applicable here to only 5 activities which involved lowering or lifting operations by Ahmed et. al[26].

This paper also investigates the existing literature and application of NIOSH prior to 1981, and the necessary parameters effecting development of NIOSH equation over time keeping in consideration the factors like load to be lifted, height of lifting, angle of movement of individual after lifting the load, recommended weight limit (RWL) and maximum permitted limit (MPL). While revising the earlier published equation in 1981 to 1985 and extending a new version in 1991, the biomechanical, physiological and psychophysical criteria were also focused upon to improve health conditions by ascertaining the load lifting capacity by making it more accurate and precise with exact numeric load values. The revised NIOSH equation also emphasizes on hand to hand coupling grip with consideration of time and frequencies and evaluations based on wide range of lifting tasks as also shown in calculations by Waters et al.[14].

Both the NIOSH lifting equations published in 1991 and the revised equation was developed to meet the research needs of Occupational Health issues and resolve Musculoskeletal Injury issues. Both the equations aimed to decrease the prominence of lower back pain developed due to load lifting amongst workers. However, the equation was not applicable to all kind of lifting conditions due to certain restrictions. Therefore, according to author, the application of Lifting Equation to common lifting conditions involves the violation of few restrictions. These violations are permissible depending on researcher's knowledge as conveyed by Dempsey[6]. A study conducted by Chauhan et. al on musculoskeletal disorders of agro workers reveals the discomfort levels in farming activities where farmers reported both physical (62.74%) and mental stress (60.78%) and a feeling of depression (58.16%) using a questionnaire. The NIOSH equation applicable to these farmers also report high Li index pre-assessment which means a significant hazard. After changing the lifting techniques, post assessment application of NIOSH equation shows much lower Li and a method of ANFIS was used to predict mental stress of farmers[27]. Barbosa et. al worked in the field of Work-related Musculoskeletal Disorders by prioritizing the ergonomic intervention in the field on textile industry in Portugal for

various twisting activities performed by them. The results obtained through detailed ergonomic workplace analysis and Nordic questionnaire with application of NIOSH and RULA method show the prevalence of musculoskeletal disorders in lumbar region and shoulders[30]. The authors created a MultiGEI model (Multitask General Exposure Index) which involves the assessment of repeated motions and exertions on upper limb and the effects of manual lifting, being applied to various sectors of agriculture, packaging, retail, construction, healthcare etc. The type of activity, duration and frequency were mainly taken in observation with OCRA and RNLE to generate MultiGEI index by Colombini et. al, thereby generating a risk score of the basis of versatile operations in a particular sector[31].

The spine of the Coupling midpoint (MC) depending on hand tools and equipment design is another major factor which if is not measured with accuracy may impact the errors in final results as confirmed by Garg[7], Van Der Beek et al.[1], Dempsey et al.[5] and Dempsey[6]. The coupling midpoint calculation affects the other dependent variables, thereby resulting in an error in determining the Recommended Weight Limit, which is an important parameter and should be defined with great precision. An error of 0.1 m in the horizontal direction results in an error up to 30% in the calculation of Recommended Weight Limit shown by Waters et. al [15]. Dempsey[6] and Waters et. al[15] focus on the deviations in calculation of variables for the NIOSH Lifting Equation sometimes end up in entirely different results. Ahmad & Muzammil focused on application of revised NIOSH lifting equation (RNLE) on 44 workers (22 male and 22 female) to derive maximum acceptable weight limits (MAWL) for these workers. The study reveals the effect of change in age, BMI and gender is statistically significant on MAWL but height and acromial height has no statistical significance, so MAWL was evaluated as 19.3 Kgs for 75 percentile women as per RNLE guideline[28]. Ahmad & Muzammil also worked on evaluation done by revised NIOSH equation to build up a better version by modifying the multipliers to make it more realistic. The concept behind changing the multipliers is to consider the individual worker with his environmental conditions thus making RWL values more accurate[29]. The study here reveals the application of altered NIOSH Lifting Equation with respect to real time situation with details and procedures of all measured parameters contributing to the final result with accurateness of measured variables.

The Recommended Weight Limit (RWL) is obtained through the relation:

$$RWL = L_C \times H_M \times V_M \times D_M \times A_M \times F_M \times C_M$$

After calculation of Recommended Weight Limit for a manually lifted load, a ratio is generated between the Recommended Weight Limit and the actual load. This ratio is known as Lifting Index (LI), which actually helps in approximation of the body stress developed during the lifting task.

This relation is summarized as:

$$LI = L/RWL$$

L is defined as Load or weight of the object to be lifted (in Kg).

The Lifting Index (LI) is categorized in three parts. The LI score of less 1.0 than specifies a safe job. LI score in the range of 1.0 to 3.0, is precarious for some workers. The increasing LI, score illustrates the risk associated with the occupation. A LI score in range of 3.0 and above is highly hazardous, but the scores do not follow a linear graphical function in terms of the level of hazards developed through lifting tasks says Garg [7].

Occupational exposures of hand-arm vibration were extensively associated with MSDs of the shoulder and neck for workers engaged in agriculture. There were consistent findings that repetitive awkward postures and recurring movements while doing regular tasks were also associated with MSDs across study designs, populations, and countries as presented by Charles et al.[4].

RULA and NIOSH study was applied to construction workers of district Kartal of Istanbul in Turkey who were occupied in plaster mortar, metal cutting, die cutting, roofing, welding, concrete crushing and brick stacking process to make ergonomic risk assessments and derive suitable prevention methods says Qzay et al.[12] . The authors evaluated the alarming increase in injuries due to unclear farm equipment safety interventions. The study shows a considerable increase of injuries upto 5-11% among workers in agriculture occupation. Safety devices and proper worker protection standards are much required for a healthy well being (Haan et al., 2018)[8]. The study conducted at Sumul dairy (Surat, Gujrat) over 50 male and female workers in identified the prevalence of MSDs in workers due to heavy object lifting and load carrying through certain distances within the dairy farm. Lower back (35%), knee pain (18%), ankle pain (8%), neck and wrist (4% each) and shoulder pain 2% is common among dairy workers of age 25 to 40 years as shown by Mishra et al.[9].

The authors studied through a purposive sampling, questionnaire and body map technique about the occurrence of MSDs in female workers, with agriculture being one of the hazardous industries. Frequent squatting, stooping, standing, walking, bending postures for prolonged durations result in serious hazards. Proper training, rest pauses and good workstation design can help us to eradicate these issues (Chandra and Parvez, 2016). A similar study was conducted by authors on manual harvesting activity on 140 farmers of Rajasthan through Nordic questionnaire for calculation of Ergonomic risk through RULA technique which gave a grand score of more than 52 in 92% farmers thus giving directions for further research and changes as recommended by Rahul Jain et.al[13].

2. Material & Methods

The test was done at three different Dairy farms in Sikar district of Rajasthan with a random data sample of 50 workers including the data relevant to their age, height, work experience in dairy, the amount of load lifted by them. All data collection was done in real time working conditions of workers performing different tasks related to dairy farming including pruning, planting, digging, harvesting, cleaning of shed, manual milking, milk packaging, milk delivery. All these tasks involve frequent movement of muscles in awkward postures for prolonged duration and the lifting of loads without proper support thereby creating strain in body resulting in musculoskeletal disorders. The normal working duration for workers is around 12 hours with intervals of 4 hours in the morning from 4 am to 8 am, 4 hours in the afternoon from 2 pm to 6 pm and the rest 4 hours for maintenance and cleanliness and hygiene activities in dairy farm.

The NIOSH equation depends on the following parameters for calculation of RWL.

Recommended Weight Limit (RWL) = L_C x H_M x V_M x D_M x F_M x A_M x C_M

Where

- L_C, the load constant factor
- H_M, the Horizontal Multiplier factor,
- V_M, the Vertical Multiplier factor,
- D_M, the Distance Multiplier factor,
- F_M, the Frequency Multiplier factor,
- A_M, the Asymmetric Multiplier factor, and
- C_M, the Coupling Multiplier factor.

The amount of weight lifted, vertical distance covered, and the angle of movement of body actually with respect to starting plane contributes as major factor for calculation of NIOSH score. The amount of load to be carried and distance might be same for most of the workers but the coupling or gripping factor varies with an individual which decides the safe weight limit for a worker. The coupling factor depends on hand dimensions, gripping ability and weight lifting capacity of a worker Okimoto et. al [11].

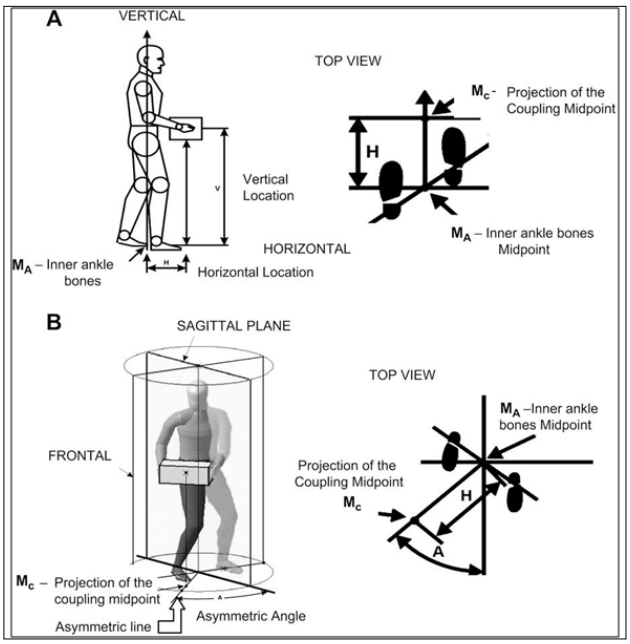

Fig 1. M.L.L.R. Okimoto, E.R. Teixeira / International Journal of Industrial Ergonomics 39 (2009) 15–22.

The assessment of the task was based on the observations of the workers and their interview regarding the load values, horizontal and vertical movements, task's duration and frequency variables. These observations continued for 4 days for duration of 2 hours every day. As the tasks described in table illustrates that the normal lifting/loading varies to a height of 60-65 inches for a load of 30-40 Kgs in form of milk containers and manure lifting on head which develops a incessant stress on neck joint, shoulders muscles till the lifting is completely over. Both the tasks described in table are done frequently with manure lifting for 40-50 times or even more in a day depending on farm area and the number of manual dairy workers and lifting of milk 20-25 cans twice a day or even more depending on the scale of milk production.

Using the NIOSH tabulation method the values of RWL (Origin) and RWL (Destination) have been calculated for all 50 workers and the Li (Average) values have been defined. The following graphs were drawn as per the data received from dairy farm workers and the further RWL and Li calculations made.

Table 1. Manual Load Lifting Analysis Chart

Industry	**Dairy Farm**	**Job Description**
Task 1	Cleaning manure daily	The task involves cleaning and pick and place of cowdung, manure from source to destination which involves lifting of 30-40 Kgs of weight upto an average height of 65 inches from ground level and drop at a distance of 100 metres within the farm area.
Analyst Name	Vinod Sharma	
Date	22nd Nov 2021	
Task 2	Delivering milk cans	The task includes lifting of milk cans of weight 35-40 Kgs in form cylindrical drums to be placed in open trucks at a height of 50 inches from ground level.
Analyst Name	Vinod Sharma	
Date	24th Nov 2021	

Table 2. Manual Load Lifting Analysis (Worker Details)

Details of Worker				**Weight of Object (Kg)**	
Name of Worker	**Age**	**Dairy Work Experience**	**Object weight Minimum**	**Object weight Average**	**Object weight Maximum**
Subject A	53	15	18	33.5	49

Table 3. Manual Load Lifting Analysis (Hand Movement)

Hand Location (in)				
Hand location Origin (in) Horizontal (Ho)	**Hand location Destination Horizontal (H_D)**	**Hand location Origin (in) Vertical (Vo)**	**Hand location Destination Vertical (V_D)**	**Vertical Distance covered (D)**
5	14	10	65	55

Table 4. Manual Load Lifting Analysis (Angle & Grip)

Angle of rotation of body (degrees)		**Time of lifting and grip factor**		
Assymetric Angle Degrees Origin (A)	**Assymetric Angle Degrees Destination (A)**	**Frequency Rate lifts/min (F)**	**Duration**	**Object Coupling**
5	40	0.2	LONG	Fair

Table 5. Manual Load Lifting Analysis (Rwl Calc)

Final Outcome				
RWL Origin	**RWL Destination**	**LI Origin**	**LI Destination**	**LI Average**
29.37	16.98	0.61	1.06	0.835

3. Research Findings & Discussion

The Lifting index (average) data shows that the majority of workers in dairy farm industry who are regularly involved in lifting heavy loads of average 40 Kgs from origin to destination suffer from musculoskeletal disorders. Fig 3 and 4 shows an approximate of 75-80% of workers fall in the category of those who have developed MSDs over time after working for a considerable duration in dairy farming occupation. The study was conducted on workers of age 25 to 65 years and the risk of musculoskeletal disorders developed with increasing age. Fig 5 and 6 with Li destination and Li Average show a linear growth in lifting index or risk score with respect to increasing age and the more of time spent in dairy industry. The recommended weight limit follows a trendline with respect to age. Fig 7 shows an optimum Recommended Weight Limit (RWL) given by the polynomial equation which constrains the max permissible limit of load for an individual with increasing age to avoid musculoskeletal disorders. Fig 8 shows that the more workers get experienced in dairy and spend time in dairy farm activities, the higher level of risk order is developed in their body muscles thereby resulting in serious injuries and permanent deformations in the body due to strain developed in load lifting, if not cured at the right time.

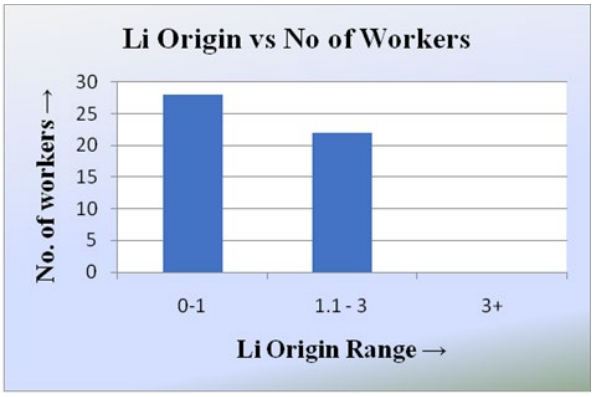

Fig 2. Lifting Index (origin) score for 50 dairy farm workers

Fig 3. Lifting Index (destination) score for 50 dairy farm workers

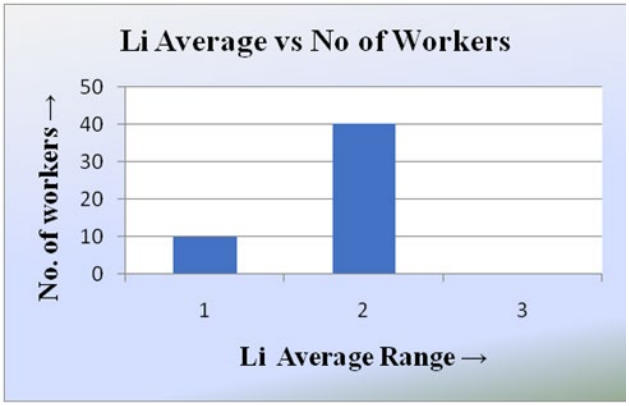

Fig 4. Lifting Index (Average) score for 50 dairy farm workers

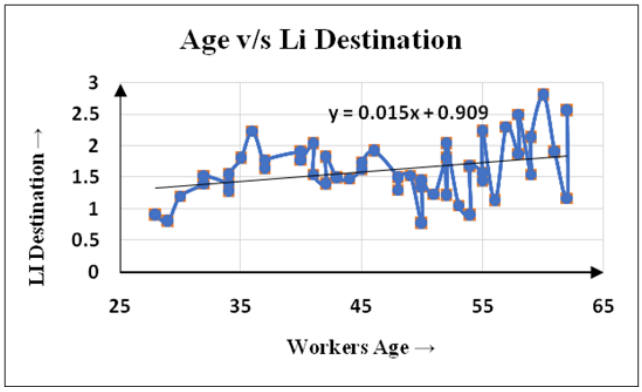

Fig 5. Age vs Lifting Index (destination) score for 50 dairy farm workers

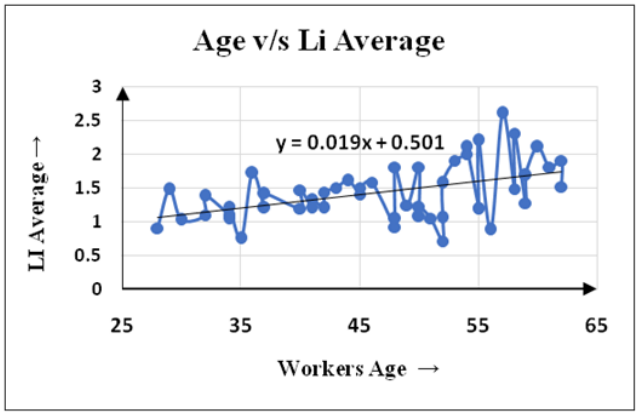

Fig 6. Age vs Lifting Index (average) score for 50 dairy farm workers

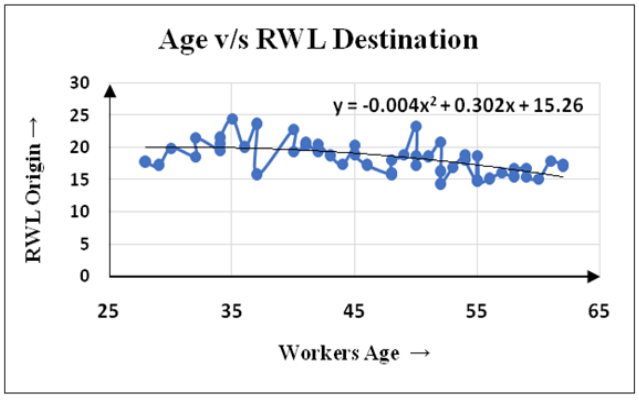

Fig 7. Age vs RWL destination score for 50 dairy farm workers

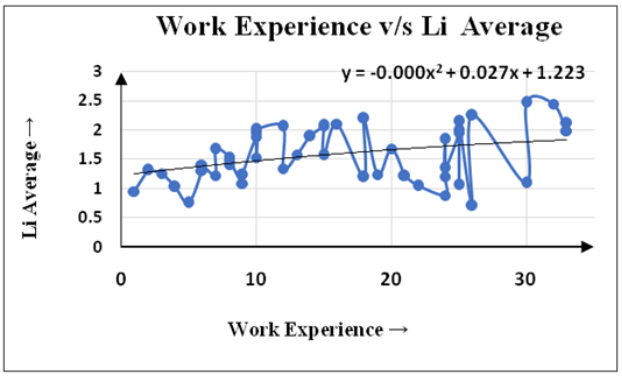

Fig 8. Work Experience vs Lifting Index (Average) score for 50 dairy farm workers

4. Conclusion

The study reveals that there are frequent load carrying and material handling activities in dairy farming for manual workers and they are prone to higher level of musculoskeletal disorders due to heavy load movements vertically and horizontally within the dairy farm. The results derived through NIOSH equation shows that MSDs are common in manual dairy farm workers and the level of MSDs increase with increasing age and experience in dairy industry. Approximately 75-80% workers suffer from of mild or heavy level of MSDs with respect to lifting index risk scores obtained through the data. A permissible level of weight limit RWL is calculated for dairy workers depending on their age, experience and the amount of load carried by them during their daily tasks. The calculations through NIOSH equation mainly focus on lifting height, asymmetrical angle, duration of lift and the object gripping or coupling factor for an individual. The MSDs prevalence due to frequent load lifting, awkward bending, squatting, kneeling, twisting can be eradicated with the help of proper protection equipments, training, proper rest pauses and developing a good workstation design.

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