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Case Study

Ergonomic Evaluation on Chicken Feeder Tool at Egg-Laying Chicken Farm SME

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A B S T R A C T

This research aimed to evaluate the chicken feeder tool that was designed for small and medium enterprise (SME) of egg-laying chicken farm. The main reason of this tool design was due to the worker's complain of feeling pain during the feeding process. The evaluation was performed based on Nordic Body Map questionnaire result, physiological workload, and NIOSH lifting equation calculation. The observed work ranged from the feed filling in the basket until all feeds were distributed. The results showed that the %CVL was in the range of 18%-30% and the energy consumption of workers was in the range of 1.24-3.00 Kcal/minute. Thus, physiologically, the work activities carried out by the feed workers were categorized as very light workload. Meanwhile, evaluation using Lifting Index (LI) methods in the process of feeding showed the LI value ranged from 0.9-1, therefore this activity is safe to perform manually. Based on the prototype evaluation on the feeding aid, the process of feeding activities was more effective 1.5 times faster than the old tools. In addition, with the use of this new tool, the feeding process was easier to adjust the dose each time.

INTRODUCTION

Nabila Farm is Small and Medium Enterprise (SME) of an egg-laying chicken farm established since 2000 in Jorong Parumpuang, Nagari Koto Baru Simalanggang, Payakumbuh City, West Sumatra. It produces around 56,400 eggs a day with distribution areas covering cities of Pekan Baru, Jambi, Bengkulu and Jakarta. However, this number cannot meet the demand from retailers with an average demand of around 70,000-80,000 items per day. Thus, in order to increase production output, improvements in the production flow should be initiated.

One of the factors that results in the inefficient production flow is because the workers generally still carry out manual work activities using simple slings, thus the feeding process for a row of cages with a capacity of ± 3800 chickens takes 65-75 minutes and this method results in a large amount of feed being wasted. It is proven that every day the SMI distributes feed for one row of cages with a capacity of 3800-4000 chickens totaling 560 kg. In fact, the need for feed for one chicken is around 125 g/day, so the need for feed for one row of cages is 475 kg. This shows that there is a waste of ± 85 kg/day/row. Figure 1 shows the feeding activity carried out by workers every day.

In previous research conducted by Putri et al. [1], the animal feeder was designed using the ergonomic function deployment method and the canoe method. These methods develop and plan a product by defining it based on consumers' desires and how much the product can fulfill and satisfy consumers. The results of this design have been adjusted to the anthropometry of the feeding workers and the size of the chicken's coop, thus the tools produced do not change the state and size of the cage. Figure 2 is the result of the selected design of the feeder.

The selected design was then made into a prototype. Figure 3 is the prototype of the feeder. Several studies have been conducted

Figure 1. Feeding Activity

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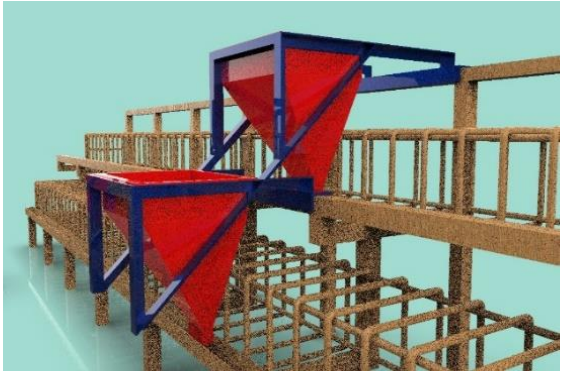


Figure 2. Selected Design of the Egg-Laying Chicken's Coop

Figure 3. Feeder Prototype

by previous researchers related to the ergonomic evaluation of tool design result. The use of the NIOSH lifting equation model is one of the evaluation tools to determine the effectiveness of ergonomic interventions including engineering/technical and organizational interventions, stakeholder involvement in reducing musculoskeletal risk factors/symptoms and for ergonomically balancing and redesigning workstations in the workplace [2]. In addition, other studies use the AHP approach based on the evaluation stage or the computer design design process [3].

Another research used Low Back Analysis (LBA), Ovako Working Posture Analysis System (OWAS), and Rapid Upper Limb Assessment (RULA) to determine the optimal design configuration of a folding bicycle based from an ergonomics perspective. For male and female riders, the optimal configuration was obtained when the height of the hand width is 32 cm and the height of the saddle is 83 cm. This study proved that a virtual environment could strengthen the ergonomics evaluation, especially in posture condition exploration [4] and other researcher used anthropometry, biomechanics, and physiological to reduce spinal injury by identifying factors resulting from lifting loads that exceed the limits of the body, calculate the maximum load limit that can be carried by a soldier, and produce artificial exoskeleton as a tool for the Indonesian Armed Forces [5].

A field study used Ratings of Perceived Discomfort (RPD) and Automotive Seating Discomfort Questionnaire (ASDQ) to evaluate a truck seat prototype in comparison with a standard seat. Participants reported significantly higher discomfort scores when sitting in the industry standard seat. Participants sat with more lumbar lordosis and assumed a more extended thoracic posture when seated in the prototype. Pairing the gluteal backrest panel with the adjustable seat pan also helped reduce the average sitting pressure on both the seat pan and the backrest. The prototype provided several postural benefits for commercially certified truck drivers, as it did for a young and healthy population [6]. Another study used an integration between the Automation System Group (ASG), Postural Stress Screening Module (PSSM) and Physical Fatigue Screening Module (PFSM) to evaluate a model for postural risk and metabolic workload [7].

Several studies have integrated several methods for carrying out ergonomic analysis of designed products, such as integration between the Posture Evaluation Index (PEI) method with LBA, OWAS and RULA for evaluating actual bike UI design and seek the most ergonomic redesign configuration [8]. Another study used several methods in evaluating the design results such as using Kansei engineering in evaluating baby carrier products [9] and study used Rapid Entire Body Assessment (REBA) method in designing a batik dye machine to improve work posture. The machine dip dyeing work position with standing body posture scores are 2-4 with safe to low musculoskeletal level (maybe need to be corrected in longer term) [10]. Human Factors and ergonomics perspective use to evaluate surveillance systems and support the design for protection citizens and critical infrastructures [11]. Some other examine used integration of experimental research (maximum torque assignment and steady torque task) and product interactive questionnaire survey to evaluate layout of hand gear [12]. Evaluate the design result by measuring muscle fatigue and subjective discomfort in new concept of VDT workstation chair with and adjustable keyboard and mouse support [13].

Integration between fuzzy decision-making trial and evaluation laboratory (FDEMATEL) and six main headings to evaluate the ergonomic design of these departments with respect to specific criteria/standards is expected to contribute to the improvement of productivity and service quality since EDs have too much complexity and volume in the patient flow [14]. In medicine, the design of new handle in larosscopic surgery to reach the patient's organs without adopting extremely awkward postures has been tested in terms of efficiency, effectiveness, and satisfaction using questionnaires with objective parameters [15].

This paper aimed to evaluate a laying hen feeding aid that has been designed using the ergonomic function deployment and the Kano method. The evaluation carried out an ergonomic analysis of the feeder design by using the Nordic Body Map method, evaluation of the physiological workload by measuring the workers' pulse every minute, and evaluation of the lifting equation based on the NIOSH lifting equation.

Ergonomics

Ergonomics is a science that seeks to harmonize work and the environment with people or vice versa, which aims to achieve the highest work productivity and efficiency through optimal utilization of human factors. Ergonomics' targets are all workers, both in the modern sector and in the traditional and informal sectors. In the modern sector, the application of ergonomics is in the form of setting attitudes, working procedures and proper work planning, which are essential conditions for high work efficiency and productivity. In the traditional sector, it is generally done by hand and using tools, and postures and working methods can be ergonomically improved [16].

An ergonomic problem that often occurs in informal sector workers is musculoskeletal complaints. Musculoskeletal complaints are complaints on the part of the skeletal muscles that are felt by a person ranging from very mild complaints to very painful. If the muscles receive static loads repeatedly and for a long time, it will cause damage to joints, ligaments and tendons. This damage is usually called musculoskeletal disorders (MSDs) or injury to the musculoskeletal system [12]. The parts of the muscles that often hurt are the neck, shoulders, arms, hands, back and waist. The risk factors for developing musculoskeletal complaints are high workload, repetitive work, incorrect work posture and stress [13].

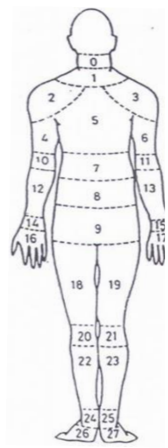
Musculoskeletal Disorders

Musculoskeletal disorder is a disorder of the skeletal muscles caused by the muscles receiving static loads repeatedly and continuously for a long time and will cause damage to joints, ligaments and tendons [11]. Studies on MSDs in various types of industry have been widely carried out and the results of the study show that the muscle parts that are often complained of are the skeletal muscles which include the muscles of the neck, shoulders, arms, hands, fingers, back, waist and lower muscles. MSDs are ergonomic problems that are often encountered in the workplace, especially those related to human strength and resilience in doing their jobs. This problem is commonly experienced by workers who do the same movements and repeat themselves continuously. The condition can be said to be unsafe if the health and safety of workers starts to have problems. Fatigue and musculoskeletal complaints are an indication of health and safety problems for workers. Workers often complain that their body feels pain or aches at work or after work.

Risk factors for MSDS can occur from repetitive work activities, such as lifting, handling manual work, sitting or standing for long periods of time [17]. In order to carry out work, especially in the types of physical work such as feed workers or garbage collectors, the health of workers is one of the dominant factors. Worker health is a valuable asset and an absolute requirement to be able to help overcome waste management in countries with low income levels. However, the protection of occupational health and safety for workers in low-income countries is not yet optimal because the limited availability and use of appropriate personal protective equipment, as well as very limited supervision, is a factor in the increasing number of work accidents [18].

Musculoskeletal complaint factors include [13]:

a. Excessive stretching of muscles, it generally often occurs in workers whose work activities require great exertion, such as lifting, pushing, pulling and holding heavy loads.
b. Repetitive activity, it is work that is carried out continuously such as hoeing, chopping large logs, lifting and so on. Muscle complaints occur because the muscles receive pressure due to the workload continuously without getting the opportunity to relax.



0	Uper neck	14	Left wrist
1	Lower neck	15	Righ wrist
2	Left shoulder	16	Left hand
3	Right shoulder	17	Right hand
4	Left upper arm	18	Left thigh
5	Back	19	Right thigh
6	Right upper arm	20	Left knee
7	Waist	21	Right knee
8	Hip	22	Left calf
9	Butt	23	Right calf
10	Left elbow	24	Left ankle
11	Right elbow	25	Right ankle
12	Left forearm	26	Sole of the left foot
13	Right forearm	27	Sole of the right foot

Figure 4. Nordic Body Map [16]

c. Unnatural posture, it is a posture that causes the position of the body parts to move away from the natural position, for example, the movement of the arms raised, the back is too bent, and the head is raised and so on. Generally, due to the characteristics of job demands, work tools and work stations do not match the capabilities and limitations of the workers.
d. Secondary causative factors, those can result from direct pressure on the soft muscle tissue when the hand is holding the tool, high-frequency vibrations resulting in increased muscle contraction, and exposure to cold temperatures resulting in decreased agility, sensitivity and strength of the worker which slows down movement.
e. Combination, individual factors such as age, gender, smoking habits, physical activity, physical strength and body size can also cause skeletal muscle disorders.

Nordic Body Map

Nordic Body Map (NBM) is a subjective assessment using a body map to determine which parts of the muscle are experiencing pain with a level of complaints ranging from mild to painful [16]. The NBM method, in its application using a worksheet in the form of a body map, is a very simple way, easy to understand, inexpensive and requires a very short time. Observers can directly ask respondents which parts of the skeletal muscles are affected by pain by pointing directly to each skeletal muscle as listed in the NBM questionnaire. Assessment can then be done using an assessment design with scoring (4 liker scales). When scoring with this scale is used, each score or value must have a clear operational definition so that it is easily understood by respondents [16]. The NBM is one of the subjective measurement methods for measuring workers' muscle pain. In order to locate the pain or discomfort in the worker's body, a body map is used. The division of body parts and the description of these body parts can be seen in Figure 4 [19].

Physiological Workload

Psychological load measurement can be done by the following measurement [18]:

1. Objective physiological load measurement
   a. Heart Rate Variability Measurement
   This measurement is used to measure a person's dynamic workload as a manifestation of muscle movement. This

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method is usually combined with recording video images for motion study activities.

b. Blink Time Interval Measurement
The blinking duration can indicate the level of workload experienced by a person. People who experience heavy and tired work usually have a long blinking duration, whereas for people who work lightly (not mentally or psychologically burdened), the blinking duration is relatively fast.

c. Flicker Test
This tool can show differences in the performance of the human eye, through differences in the flicker value of each individual. The difference in flicker value is generally very much influenced by the weight/lightness of work, especially those related to eye work.

2. Subjective psychological load measurement
   a. The subjective workload assessment technique (SWAT)
   SWAT is an assessment techniques in which subjects are provided question to rate the task workload based on the criteria of time load, mental effort load and psychological stress load. These dimensions are derived from a definition of cognitive workload proposed by Sheridan and Simpson [20]. It applies conjoined measurement and scaling techniques to combine ordinal level assessments into an overall workload score.
   b. NASA-TLX
   The National Aeronautical and Space Administration Task Load Index (NASA-TLX) was developed by Sandra G from NASA Ames Research Center and Lowell E. Staveland of San Jose State University in 1981. This method was developed based on the emergence of the need for subjective measurements consisting of a nine-factor scale (task difficulty, time pressure, type of activity, physical effort, mental effort, performance, frustration, stress and fatigue). These nine factors are further simplified into six, namely Mental demand, Physical demand, Temporal (time) demand, Performance, Effort and Frustration [11].

In general, those related to workload and work capacity are influenced by various very complex factors, both external and internal. Each task is a load for those concerned. The load can be physical or mental load. Assessment of physical workload can be carried out by two methods which are [19]:

1. Direct Measurement Method
The direct measurement method is to measure energy expenditure through energy intake during work. The heavier the work, the more energy is expended. Although the method using oxygen intake is more accurate, measuring only briefly and the equipment required are very expensive [5].

2. Indirect Measurement Method
The indirect measurement method is to calculate the heart rate during work. The measurement of heart rate during work is a method for assessing cardiovascular strains using the 10 beat method. Heart rate is a good metabolic rate estimator, except in an emotional state. The category of workload severity is based on metabolic respiration, body temperature, and heart rate [21]. Apart from the heart rate method, ones can also calculate the heart rate using the 15 or 30 second method. Using a work heart rate to assess workload has several advantages. Apart from being easy, fast, and inexpensive, it also does not require expensive equipment, does not interfere with the activities of the workers being measured. Heart rate sensitivity immediately changes in line with changes in load, whether it comes from mechanical, physical, or chemical loads [13].

Heart rate is used to measure physical activity levels [10]. Furthermore, there are five classifications in % HR Reverse: 1) less than 30% indicate no fatigue; 2) 30% -60% describe the need for improvement; c) 60%-80% describe work in no time; d) 80%-100% describe urgent action is required; and e) more than 100 describe no activity allowed [22], [23]. The calculation of maximum heart rate (HR_max), heart rate reserve (HR_resv), and percentage of heart rate reserve (%HR_resv) are expressed in equation (1) – (3), respectively.

$$\text{HR\_max} = 220 - \text{age} \quad (1)$$

$$\text{HR\_resv} = \text{HR\_max} - \text{HR\_rest} \quad (2)$$

$$\%\text{HR\_resv} = \frac{HR\_work - HR\_rest}{HR\_max - HR\_rest} \quad (3)$$

where HR_rest denotes the resting heart rate i.e., heart rate when ones are not doing any activity which is counted for 15 seconds and multiply by four, or 30 seconds and multiply by two. The HR_work is a working hear rate i.e., heart rate when ones are doing a certain activity.

Energy consumption at work is usually determined in an indirect way, which is by measuring heart rate and measuring oxygen consumption [24]. Heart rate is a good indicator of fatigue at work. Heart rate fluctuation is an indicator of mental workload. The higher the mental workload, the lower the heart rate variability [25]. Energy consumption (EC) for specific activity can be calculated as

$$EC = Et - Ei \quad (4)$$

$$Et = 1{,}80411 - 0{,}0229038\,(x) + 4{,}71733 * 10^{-4}\,(x)^2 \quad (5)$$

Equation (4) describes energy cosumption (EC) for spesific activities (Kkal/min) where *Et* denotes energy expenditure during working time while *Ei* denotes denotes energy expenditure during resting time. Equation (5) represents the calculation of *Et*.

The pulse rate to estimate the workload index consists of several types. It s determined by either of [11]:

1. Heart rate during rest (resting pulse) is the average heart rate before a work begins.
2. Heart rate during work (working pulse) is the average heart rate when a person is working.
3. Heart rate for work (work pulse) is the difference between the heart rate during work and during rest.
4. Heart rate during total rest (recovery cost) is the algebraic sum of the heart rate and the stop beats during a work done until the beat is in a resting state.
5. Total work heart rate (cardiac cost) is the number of heartbeats from the start of a job until the pulse is at resting level.

The rate of recovery of the pulse is influenced by the absolute value of the pulse in the interruption of work, individual fitness, and environmental heat exposure. If the recovery pulse is not reached immediately, it is necessary to redesign the work to reduce physical stress. The redesign can be in the form of a single

Table 1. Workload Category Based on Oxygen Consumption, Body Temperature and Heart Rate [13]

Workload Category	Oxygen Consumption (l/min)	Pulmonary Ventilation (l/min)	Temperature (^{0}C)	Heart Rate (beat/min)
Light	0.5-1.0	11-20	37.5	75-100
Medium	1.0-1.5	20-30	37.5-38.0	100-125
Heavy	1.5-2.0	31-43	38.0-38.5	125-150
Very Heavy	2.0-2.5	43-56	38.5-39.0	150-175
Extremely Heavy	2.5-4.0	60-100	>39	>175

variable or the whole of the independent variables (tasks, work organization, and work environment) which cause additional workloads [10].

This research calculated the energy consumption to measure the level of activity. There are five levels of activity i.e. Extremely Heavy, Very Heavy, Heavy, Moderate, Light, and Very Light [26]. NIOSH Lifting Equation can be used to evaluate a complete manual lifting task or parts of the task so as to reduce the overall possibility of lower back pain or injury. To aid in the prevention of lifting-related lower back injury, NIOSH developed the Revised NIOSH Lifting Equation (RNLE), to calculate a recommended weight limit (RWL), and lifting index (LI) used for estimating the physical demands of the job [9]. The equation for determining the recommended load for a worker in performing lifting task under certain conditions according to NIOSH is as follows [6]:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \quad (6)$$

The calculation of the Lifting Index aims to determine the lifting index that does not contain a risk of spinal injury, with the following equation [17]:

$$LI = \frac{Load\ Weight}{RWL} \quad (7)$$

If LI> 1, the weight lifted exceeds the recommended lifting limit, then the activity has a risk of spinal injury. If LI <1, the weight lifted does not exceed the recommended lifting limit, then the activity does not have a risk of spinal injury [27]. Table 1 shows workload category based on oxygen consumption, body temperature and heart rate [13].

METHOD

The procedure of this research was carried out through several stages.

Stage 1: Collecting Data

This study aimed to assess workers' complaints using the Nordic Body Map questionnaire, examining the worker's physiological load by measuring the increase in work pulse compared to maximum pulse rate (% CVL) and calculating energy consumption, analyzing the risks posed by manual material handling activities using NIOSH Lifting Equation [25].

The data collected in this study were: (1) Complaints on the body parts of workers when using tools; (2) Heart rate before feeding process; (3) Heart rate after feeding process; (4) Worker's body size; (5) Chicken coop size.

The research was conducted on feeding workers at CV Nabila Farm, Payakumbuh, Indonesia. The data needed for the study were the layout data for the feeding process, the stages of the feeding process using tools, the pulse of workers before and after the feeding process using tools, vertical distance, horizontal distance, subjective perception of the operator and time study for lifting process [28]. Data collection was carried out by distributing NBM questionnaires, measuring workers' pulse before and after feeding, measuring horizontal distances, vertical distances, and load transfer distances during the feeding process [13]. The results of the data processing were used to determine whether the feeding job using tools had solved the ergonomic problems faced.

Stage 2: Filling Out the NBM Questionnaire

NBM questionnaire was used to compare the pain or discomfort felt by workers before and after using the design aids.

Stage 3: Physiological Workload Measurement

This measurement is carried out to measure energy consumption and energy production so as to determine the work category.

Stage 4: Recommended Lifting Weight Analysis

It is to find out the limits of free lifting that are doable by the workers. The result of the tool design is intended to assist the workers in distributing the feeds to every row of the pens, therefore the tool filling process is still performed manually by the feeding workers.

RESULT AND DISCUSSION

The NBM questionnaire was given to 13 feeding workers to see the complaints felt by workers. The results of the NBM questionnaire can be seen in Table 2. The instructions for filling out the NBM questionnaire can be seen in Table 3.

Based on the results of the NBM questionnaire, it was obtained a value of 42, which based on Table 4 is categorized as low and does not require improvement in work posture. Based on the evaluation results of the feeding tools, 9 of the 27 sections in the NBM questionnaire were the parts that were used as the focus when designing the tools. The results of this evaluation showed that 7 of the 9 parts had been repaired by the use of tools, they were the upper neck, nape, left and right shoulders, left and right thighs, and calves, but the back and waist still experienced pain or discomfort when using this tool because during the process of pushing the tool, the worker's body has to bend a little. This means that the use of designed tools can overcome the pain complaints felt by workers due to the use of slings.

Physiological workload is carried out by paying attention to an increase in the work pulse compared to the maximum pulse. Table 5 shows the physiological workload classification based on increased work pulse while Table 6 shows classification of

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Table 2. NBM Results

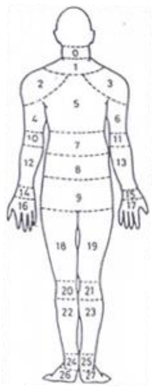
Musculoskeletal	Scoring				NBM	Musculoskeletal	Scoring			
	1	2	3	4			1	2	3	4
0. Upper Neck	√					1. Lower Neck			√	
2. Left Shoulder		√				3. Right Shoulder		√		
4. Upper Left Arm		√				5. Back		√		
6. Upper Right Arm		√				7. Waist			√	
8. Hip	√					9. Bottom	√			
10. Left Elbow		√				11. Right Elbow		√		
12. Lower Left Arm	√					13. Lower Right Arm	√			
14. Left Wrist	√					15. Right Wrist	√			
16. Left Hand	√					17. Right Hand	√			
18. Left Thigh	√					19. Right Thigh	√			
20. Left Knee	√					21. Right Knee	√			
22. Left Leg		√				23. Right Leg			√	
24. Left Ankle	√					25. Right Ankle	√			
26. Left Foot	√					27. Right Foot	√			
Sum Score Right			19			Sum Score Right				23
Individual Sum Score	**MSDs**									**42**

Table 3. High Request of Nordic Body Map

Degree of Pain	Score	Degree of Pain	Score
No pain	1	Pain	3
Rather Pain	2	Very Pain	4

Table 4. Total Score of Nordic Body Map

Score	Individual Sum Score	Degree of Risk	Improvement
1	28-49	Low	Doesn't need improvement
2	50-70	Medium	Maybe need improvement
3	71-91	High	Need Improvement
4	2-112	Very High	Need Improvement as soon as Possible

Table 5. Physiological Workload Classification Based on

%CVL	%CVL Classification
<30%	No Fatigue
30%-60%	Needs Improvement
60%-80%	Short-Time Work
80%-100%	Needs Immediate Action
>100%	Not Allowed for Activity

Table 6. Classification of Physiological Workloads Based on Energy Consumption and Energy Produced

Workload Classification	Oxygen Consumption (liter/sec.)	Exerted Energy (Kcal/hour)	Heart Rate (dpm)
Very Light	0.23-0.33	75-100	60-80
Light	0.33-0.5	100-150	70-90
Moderate	0.5-1.0	150-300	80-110
Heavy	1.0-1.5	300-450	100-130
Very Heavy	1.5-2.0	450-600	120-150

physiological workloads based on energy consumption and energy produced.

Physiological workload is carried out by paying attention to an increase in the work pulse compared to the maximum pulse. Table 5 shows the physiological workload classification based on increased work pulse while Table 6 shows classification of physiological workloads based on energy consumption and energy produced. The results of the calculation of energy consumption showed that the workload was in the very light category. The calculation showed energy consumption while working was in the range 1.24 - 4.42 kcal/minute as shown in Table 7.

The determination of the workload is based on the increase in the work pulse through comparison with the maximum pulse due to the cardiovascular load (% CVL). Cardiovascular load before designing aids for feeding laying hens was in the range of 30-70%. This shows that it is necessary to make improvements by designing tools to reduce physical fatigue experienced by workers. After testing the tools that have been designed and the measurements made again, it is found that the% CVL value of the workers has decreased drastically until it is in the range of 18-37%. This means that workers do not feel tired when using the aids for feeding laying hens. The physiological workload calculation on the results of the tool design showed that the feeding process was categorized as Very light workload. It can be interpreted that the results of the feeding tool design can reduce the physical workload of workers.

The purpose of the recommended lifting weight analysis is to find out the limits of free lifting that are doable by the workers. This analysis was carried out using the Recommended Weight Limit (RWL) to determine the limit so that from these results, if a larger RWL value is obtained, the better, this is because workers will be able to lift the heaviest load according to the RWL value without experiencing injury.

Table 7. Calculation of the Physiological Workload of Feeding

Worker	After Improvement				Energy (Kkal/s)	Description
	Heart Rate		Energy Expenditure (Kkal/s)			
	E_i	E_t	E_i	E_t		
Worker 1	68	98	2.43	4.09	1.66	Very light workload
Worker 2	80	110	2.99	4.99	2.00	Very light workload
Worker 3	77	100	2.84	4.23	1.39	Very light workload
Worker 4	63	98	2.23	4.09	1.86	Very light workload
Worker 5	73	95	2.65	3.89	1.24	Very light workload
Worker 6	74	105	2.69	4.60	1.91	Very light workload
Worker 7	82	137	3.10	7.52	4.42	Light Workload
Worker 8	76	102	2.79	4.38	1.59	Very light workload
Worker 9	72	107	2.60	4.75	2.15	Very light workload
Worker 10	82	123	3.10	6.12	3.03	Very light workload
Worker 11	64	92	2.27	3.69	1.42	Very light workload
Worker 12	77	110	2.84	4.99	2.16	Very light workload
Worker 13	64	112	2.27	5.16	2.89	Very light workload

Table 8. Summary for Recommended Weight Limit and Lifting Index

Multiplier	Formula	Parameter Origin	RWL (kg)	LI	Parameter Destination	RWL (kg)	LI
Load Constant (LC)	15	15 kg			15 kg		
Horizontal (HM)	25/H	H = 38 cm			H = 21 cm		
Vertical (VM)	1-(0,03 | V-75 |	V = 21 cm			V = 132 cm		
Distance (DM)	0,82-(4,5/D)	D = 21 cm	16.24	0.92	D = 37 cm	19.9	0.79
Asymmetry (AM)	1-(0,0032 x A)	A = 0^0			A = 0^0		
Frequency (FM)	Table Frequency Multiplier	1 lifts/min			1 lifts/min		
Coupling (CM)	Good, Fair, Bad	Fair			Fair		

The result of the tool design is intended to assist the workers in distributing the feeds to every row of the pens, therefore the tool filling process is still performed manually by the feeding workers. Figure 5 shows worker's posture during feeding process using the tool. Figure 6 shows the manual feed lifting process using the tool. Table 8 shows the data of manual material handling process of the feed.

The calculation result of the recommended weight limit and lifting index shows that the feed filling process into the tool did not cause injury on the workers, although performed manually, because the value was LI<1. RWL value of the filling process is 19.9 kg, which implies that the maximum load that a worker can lift manually to avoid injury is 19.9 kg.

CONCLUSION

Based on the Nordic Body Map questionnaire result given to 13 feeding workers, there are significant changes on the workers' body. There are no more pains felt by the workers on their upper neck, back, waist, and shoulder. The %CVL and energy

Figure 5. Worker's Posture using the Designed Tool

Figure 6. Feed Filling Process into the Designed Tool

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expenditure calculation that have been measured to know the physiological load of the workers show that the feeding process using the designed tool is included under the very light load category, and based on the NIOSH manual lifting calculation, the feed filling process into the tool did not pose any injury risk although performed manually because the recommended load for manual work is 18-20 kg, while the average weight the workers lift is 15 kg. Based on the evaluation, it shows that the designed feeding tool is able to reduce the complaints from both the workers and the company. This can be seen from the fact that there is no longer any wasted feed and the feeding process has accelerated two times faster than before.

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NOMENCLATURE

Y	:	Energy (kcal per minute)
X	:	Heart rate (beats per minute)
EC	:	Energy consumption for a certain work activity
LC	:	Load Constant
HM	:	Horizontal multiplier
DM	:	Displacement multiplier
AM	:	Asymmetric multiplier
FM	:	Frequency multiplier
CM	:	Coupling multiplier
VM	:	Vertical multiplier
H	:	Distance from palm to midpoint between 2 heels (projected on floor)
V	:	Distance between the hands and the floor
D	:	Distance between the vertical height difference between the destination and origin of the lift
F	:	Average number of lift / minute over a 15 minute period
A	:	Angle between the asymmetric line and the middle of the sagittal line

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