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Workplace and Gravity: Two Mechanized Cow Milking Systems Compared for Human Physiological Strains

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Abstract

Despite the development of dairy farm mechanization, milking operations are still associated with heavy workloads which result in human physiological strains. This study investigated the role of gravity force in the linkage between load carriage and workers' physiological strains in milking work tasks of two major cow milking systems (milking in stanchion barns and tandem parlors). These two milking methods similarly included washing the teats, attaching the cluster, and detaching the cluster. Human energy expenditure (EE) was calculated and load carriage direction in comparison with gravity (LCG) was tracked among twenty-four male workers. The highest heart rate (107 beats min^{-1}) and EE (35.5 kJ min^{-1}) were reported for attaching the cluster in the tandem parlor milking method. Tandem parlor milking caused higher human physiological strains and higher proportions of converse LCG compared with stanchion barn milking. By developing dairy farm mechanization from stanchion barn to tandem parlor, cow milking workers are induced to apply higher forces including converse LCG causing higher human physiological strains. Mechanization of dairy farms should be developed not only for improving the rate of work and performance but also for making conditions toward a reduction in the use of human physical forces.

Keywords: Energy expenditure, Load carriage, Stanchion barn, Tandem parlor

Introduction

Agricultural mechanization has been a key factor in improvement of performance and work speed in recent decades (Hasantabar *et al*., 2019). Meanwhile, occupational health issues have not been considered as wide as work speed and performance, and labor-intensive activities and ergonomic challenges are still prevalent among agricultural subsectors (Javidi Gharacheh and Khojastehpour, 2016; Gholami *et al*., 2017; Hayati *et al*., 201 8a). Even, in some cases, farm workers suffer from ergonomic problems although they use farm machinery because these machines do not match properly with their operators' anthropometric dimensions (Rostami *et al*., 2015). Dairy farm is one of the agricultural subsectors in which the workers are exposed to hazardous situations concerning occupational risk factors (Jakob and Rosecrance, 2018).

Dairy production was one of the first livestock operations that has been mechanized (Puckett, 1980). However, the stanchion milking method as a traditional one, in which the cows are tied up, is still a common cow milking method (Hayati *et al*., 2015a; Hayati *et al*., 2018b). The dairy farm production

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system, in both traditional and mechanized systems, involves many of the work tasks associated with risk factors such as repetitive and forceful movements, awkward postures and load carriage (Nemeth *et al*., 1990; Ahonen *et al*., 1990; Hayati *et al*., 2015b). Employees within dairy farm activities, regularly work with heavy loads. The continuous load carriage is accounted for as a reason for low back pain and joint degeneration and elevating the risk of muscle fatigue and injury, and the physiological strains of activities will be higher when carrying the load (Taylor *et al*., 2016).

Physiological-based studies addressed the ergonomic problems in milking systems and partly investigated the workplace design and equipment as the effective factors in the milking operations. For example, the effects of working height, and vertical and horizontal distances between the worker and the cow on muscular and energy loads (Vos, 1974; Nemeth *et al*., 1990) and a decline in cardiorespiratory loads by installing automatic milking units (Perkiö-Mäkelä and Hentilä, 2005) were introduced as physiological issues related to the milking operation workplace. However, the role of gravity through the variations of human physiological strains in dairy farms has still not been investigated.

Gravity and human physiological strains were studied in some areas. Studies about relationships among equipment design, gravity, and physiological strains suggested that loads carried close to the body's center of gravity exert the least physiological strain (Taylor *et al*., 2016). Physiological strains applied to the climbing workers of traditional date fruit harvesting were affected when changing the approximate angle between their moving direction and gravity force (Marzban and Hayati, 2018). These were some studies about the linkage between load carriage and physiological strain in various areas, which could be considered in the dairy farm area. Lack of such studies in the dairy farm area encouraged us to investigate the role of gravity in the linkage between load carriage and workers' physiological strains in cow milking work tasks.

Materials and Methods

Milking methods and work tasks

Milking in a stanchion barn (a type of tethering system) and milking in a tandem parlor (a type of loose-housing system), as two major methods, were considered in the present study (Fig.1). Tandem parlor milking is more mechanized than the stanchion one. Work tasks of stanchion and tandem milking systems were similarly "washing the teats", "attaching the cluster" and "detaching the cluster".

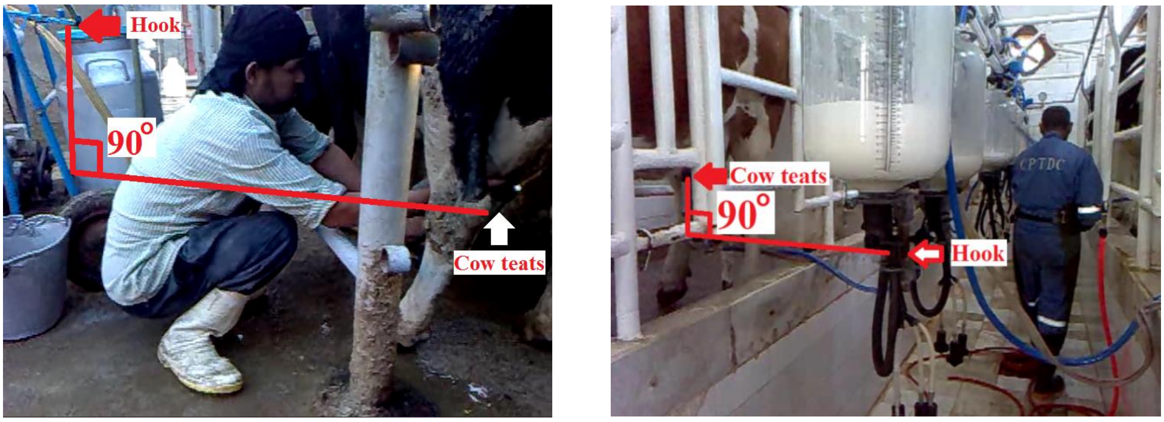

Fig.1. A stanchion barn (a) and a tandem parlor (b)

Workers were instructed to perform given job tasks at the normal routine times. After familiarizing the worker with their instruction, work tasks' cycle times were recorded using a stopwatch. Average cycle times in stanchion and tandem milking systems were 15.5 s and

9.75 s, respectively, for washing the teats, 15.25 s and 9.5 s for attaching the cluster, and 7 s and 4.75 s for detaching the cluster.

In washing the teats in the stanchion milking method, the worker takes a little water from a bucket full of water by a bowl and strews it on the teats in a squatting posture, and washes the teats associated with massaging the teats by the right hand. This work task is performed in the tandem method with the following manner: worker holds the water's hose by the left hand in a standing posture as the cow is at a higher level than the worker and washes the teats associated with massaging the teats by the right hand. In attaching the cluster in both methods, the worker takes the cluster from its hook, carries, and installs it on the teats. Detaching the cluster was performed as follows: the cluster is uninstalled from teats, carried, and put on its hook. Attaching and detaching the cluster were carried out with walking and standing postures in the tandem parlor and with stooping and squatting postures in the stanchion barn.

A cluster, in both milking methods, weighed about 2.6 kg, which consisted of a claw piece and four liners, shells, short milk tubes, and short pulsation tubes. The mass of a part of a long milk tube, a part of a long pulsation tube, water's bowl, and hose borne by hands was considered negligible.

Participants

Twelve male workers in stanchion barn and twelve male workers in tandem parlor whose job is milking, participated in this study (Table 1). They had no musculoskeletal symptoms, no medication, and at least two years' job experience. They were right-handed and had full consent to take part in this study. Three workers of stanchion barns and three workers of tandem parlors were overweight and the rest of them were in the normal range based on body mass index (Pizzol *et al*., 2020).

Table 1- Background of workers recruited in this study

Variable	Stanchion barn	Tandem parlor
No.	12	12
Gender	Male	Male
Age (year)	32.3 (±4.5)	37 (±3.6)
Height (m)	1.71 (±0.06)	1.78 (±0.05)
Mass (kg)	69 (±3.5)	78.7 (±2.3)
Body mass index (kg m^{-2})*	23.7 (±2.1)	24.6 (±2.3)

Body mass index=Mass/$(Height)^2$ (Pizzol *et al*., 2020).

Physiological strains

Heart rate, heart rate range (HRR), rate of perceived exertion (RPE), and human energy expenditure in physical activity (EE) were used to evaluate physiological strains (Table 2). Heart rate was measured by a Beurer PM 45 heart rate monitor (Beurer, Germany). The signals were transferred from the Beurer transmitter, put on the chest, to the heart rate monitor, put on the wrist. Data were recorded in temperatures between 36°C and 41°C. Physiological indexes were measured (or calculated) eight times for each participant in each work task. Means of physiological indexes were entered in statistical analysis.

Tracking the direction of load carriage in comparison with gravity

Work tasks were videotaped by a camera to track the load carriage direction in comparison with the force of gravity (LCG). LCG was classified into three major categories as follows: similar LCG: load carriage and force of gravity are in a similar direction (SLCG); converse LCG: load carriage and force of gravity are in the converse directions (CLCG); and orthogonal LCG: load carriage, in comparison with the force of gravity, is in an orthogonal direction (OLCG) (Fig.2). Each second was divided into four parts to increase the precision of video analysis. A skilled observer analyzed the videos. Data were collected with visual observation. Observational methods are reliable and valid for identifying potentially hazardous occupational jobs (Lowe *et al*., 2019). The average height level difference between hook and cow teats (Fig.1) in stanchion barns and tandem parlor was approximately measured as

0.36 m and 0.25 m, respectively. Videos were recorded for each participant with three repetitions and means of LCG values were represented. Means of LCG values were considered for statistical analysis.

Table 2- Indexes used to evaluate the physiological strains

Index*	Formula/Instruction
HR (heart rate at work)	Measured during different operations based on beats per minute (bpm)
HRR (heart rate range)	$(HR_{work}-HR_{rest})/(HR_{max}-HR_{rest})\times100$
HR_{rest} (heart rate at rest)	Measured after a 5-minute seated rest period
HR_{max}(maximal heart rate)	$205.8-0.685\times Age$
RPE (rate of perceived exertion)	Borg RPE 20 scale, ranging from six to 20 where six means “no exertion at all” and 20 means “maximal exertion”. Participant marks a point on a 14-cm bar with two anchors (no exertion (0) and maximal exertion (20)). By measuring the distance between no exertion and that point the rate of perceived exertion is shown.
EE (the energy expenditure in physical activity)	$-55.0969+0.6309\times HR+0.1988\times Mass+0.2017\times Age$

* References used: HRR (Claessen *et al*., 2019), HR_{rest} (Montes *et al*., 2019), HR_{max} (Póvoas *et al., 2020), RPE* (Garzon and Comtois, 2020), EE (Chang *et al*., 2020).

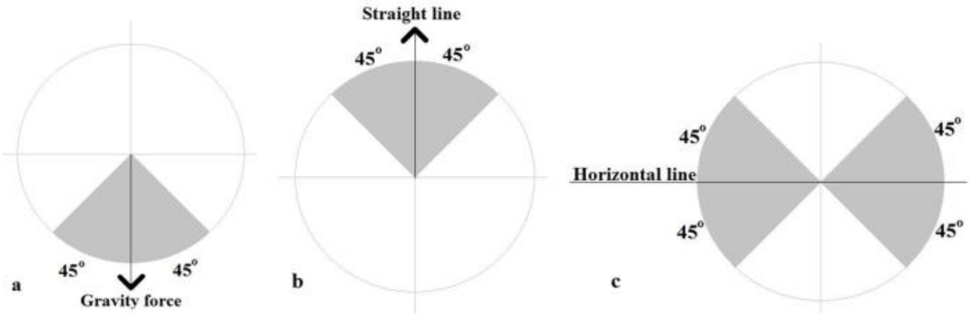

Fig.2. Load carriage directions (ranges shown with grey color) in comparison with the gravity (a: similar LCG; b: converse LCG; c: orthogonal LCG)

Statistical analysis

The data handling was carried out using IBM SPSS Statistics 24 (IBM Corporation, US). Before doing statistical analysis, the normality of the data was checked and confirmed. ANOVA, Duncan’s test, and independent samples t-test were used to compare the group mean related to the physiological indexes. Overall and partial proportions of SLCG, CLCG, and OLCG in each work task in each milking method were compared with their corresponding value in the other work tasks of that milking method using ANOVA and Duncan’s test and were compared with their corresponding value in the corresponding work task of other milking method using independent samples t-test. A value of $p<0.05$ (two-tailed) was regarded as statistically significant. A completely randomized design (CRD) was used to examine the groups with twelve repetitions (equal to the number of participants in each milking method) for each treatment. Treatments were the work tasks in ANOVA and were the milking methods in independent samples t-test. In the case of three categories of LCG, only where it was a necessity to reinforce the “results and discussion” section, categories with significant differences were mentioned and used. Regression analysis was conducted to validate the RPE-HR relationship and to investigate the predictor factors on EE. Values of milking methods were considered as a dichotomy (tandem method=1 and stanchion milking=0) in EE regression. Values of the

LCG have been presented as means based on the percent of the work task's cycle time.

Procedure

After evaluating physiological strains and tracking LCG, the role of gravity in the linkage between load carriage and workers' physiological strains in milking work tasks was descriptively discussed. Through conducting this study, validation of Borg scale based on heart rate, and linkage between milking methods and some physiological indexes were investigated.

Results and Discussion

Physiological strains

Table 3 and Table 4 show the results of ANOVA and comparison of means in terms of physiological strains. A significant difference was between the stanchion and tandem milking methods concerning each of work tasks and physiological indexes (HR, HRR, RPE, and EE). Significant differences were observed among work tasks of each milking method in the case of physiological indexes except for comparisons between washing the teats and detaching the cluster regarding HR, HRR, and EE in the stanchion method.

The heart rate is one of the important factors for workload indication (Manjarres *et al*., 2020). According to categorizing the workloads from "light work" to "extremely heavy work" based on heart rate (Astrand and Rodahl, 1986), both stanchion and tandem milking methods were classified in "moderate work". This result also supports those of other researchers (Perkiö-Mäkelä and Hentilä, 2005) who reported that the milking operation is a "moderate job" in a dairy farm. The present study introduced the tandem parlor to be higher than the stanchion barn regarding HR.

Table 3- Results of ANOVA among work tasks of milking methods with reference to HR, HRR, and EE

Variable		Source of variance	Degree of freedom	MS	F
HR	Stanchion barn	Treatment	2	51.63	15.98**
		Error	33	3.23	
	Tandem parlor	Treatment	2	480.13	154.18**
		Error	33	3.114	
HRR	Stanchion barn	Treatment	2	37.68	17.22**
		Error	33	2.19	
	Tandem parlor	Treatment	2	369.88	209.76**
		Error	33	1.76	
EE	Stanchion barn	Treatment	2	23.38	26.19**
		Error	33		
	Tandem parlor	Treatment	2	190.65	285.42**
		Error	33	0.67	

Note: ** refer to significant differences at level 0.01.

Table 4- Physiological strains in milking methods

Variables		Washing the teats	Attaching the cluster	Detaching the cluster	Average*
HR (bpm)	Stanchion barn	90.7 (±1.2)	94.6 (±1.5)	91.3 (±2.5)	92.5 (±1.6)
	Tandem parlor	100.7 (±1.2)	107.0 (±1.5)	94.3 (±2.5)	101.9 (±1.6)
HRR (%)	Stanchion barn	23.0 (±2.2)	26.2 (±0.5)	23.2 (±1.2)	24.4 (±1.4)
	Tandem parlor	31.6 (±2.2)	36.4 (±0.5)	25.6 (±1.2)	32.2 (±1.4)
RPE	Stanchion barn				10.5 (±0.8)
	Tandem parlor				11.5 (±0.6)
EE (kJ min^{-1})	Stanchion barn	22.3 (±0.9)	24.9 (±0.3)	22.6 (±1.4)	23.4 (±1.4)
	Tandem parlor	31.5 (±0.6)	35.5 (±1.2)	27.5 (±0.6)	32.3 (±1.9)

* Refer to the weighted arithmetic mean of three work tasks according to their cycle times.

This result resembles other studies where HR during the milking in parlors (97 bpm) (Perkiö-Mäkelä and Hentilä, 2005) was higher than HR in tie-stall milking (89 bpm) (Ahonen *et al.*, 1990) for men. Therefore, it can assume that milking in tandem systems is heavier than milking in stanchion ones for men which was in the inverse of the result revealed by Perkiö-Mäkelä and Hentilä (2005) for women. It may be due to the fact that walking in the tandem milking method constrains worker to have a higher physiological exertion in the present study.

The linear regression analysis to validate RPE-HR linkage in milking operation extracted a significant relationship (p-value <0.00) between HR and RPE as the following equation: RPE=0.095×HR+1.1552 (Adjusted R^2=0.644). This equation showed that by increasing the heart rate at a work, the perceived exertion of the worker to carry out that work increases. The present study was supported by other studies in which the Borg scale was introduced as valid and reliable for identifying the relationship between heart rate and rate of perceived exertion (Cabral *et al*., 2020; Williams, 2017; Penko *et al*., 2017).

Linear regression was also established including EE as the dependent variable, and HR and milking methods as the independent variables (Table 5). HR variations could not explain the EE variation, but milking methods did. The regression showed that the utilization of the tandem milking method, in comparison with the stanchion method, increased the EE by 6.265 units (kJ min^{-1}). The improvement of the mechanization level caused an increase in energy expenditure (Table 5). Indeed, it forced upon the worker to have more walking and standing during work cycle time more than the less mechanized method (stanchion method) which may be rationally accepted as a reason for increased EE. However, it decreased the time taken to perform work tasks. It highlights the addressing worker's health and comfort, besides the worker’s rate of work improvement through technology development (Almassi *et al*., 2014).

Table 5- Regression established with the dependent variable of energy expenditure (EE)

Variables	B	Standardized B	t	Sig.
Constant	23.539		21.726	0.000
Heart Rate (HR)	-0.003	-0.020	-0.225	0.823
Milking method	6.265	0.666	7.352	0.000

Model summary: R^2=0.664; Adjusted R^2=0.441; F=27.235; *p-value*: <0.000

In the present study, load (cluster) carried by workers of stanchion and tandem milking methods was approximately 3.5% of their mean body mass. Some studies reported that although HR was not significantly affected by load mass (0%, 20%, 30%, and 40% of body mass), RPE was significantly affected by increasing load mass and distance (Simpson *et al*., 2011). Others reported increased heart rate and RPE with increasing load from 0% to 50% body mass (Gordon, *et al*., 1983). In these studies and similar former studies increased load units were often equal to or over 10% of body mass. It seems partly improbable that a load of 3.5% body mass significantly affects physiological strains in the present study. But, regarding the studied milking methods, load carriages were often performed by hands in milking operations, and among four load carriage methods (rucksack, low back, across the shoulder, and in the hand), maximum physiological strains were found for load carriage by hand, besides earlier fatigue and bending of the body and deformity in posture (Malhotra and Gupta, 1965). Workers of our study may not be exempt from these risk factors. In mentioned studies (Gordon, 1983; Simpson *et al*., 2011), loads were often carried by a body part rather than hands, so the difference in physiological-based results respecting load carriage was acceptable based on the findings of another study (Malhotra and Gupta, 1965). However, it may be an interesting case for further studies to investigate various load carriage methods with various weights in cow milking operations.

The role of gravity in the linkage between load carriage and physiological strains

Table 6 and Table 7 show the results of ANOVA and comparison of means in terms of tracking the LCG. At the detaching cluster, the proportion of converse position in the tandem parlor (50%) was significantly higher than that in the stanchion barn (11%+12%) (p<0.00). In general, findings of applied physiology studies imply that physiological strains to do work including CLCG are higher compared with those including OLCG. Also, physiological strains to do work including OLCG are higher compared with those including SLCG (Brubaker *et al*., 1986; Minetti *et al*., 2002; Abe *et al*., 2008). Based on this rule, we discussed the workers' physiological strains as follows:

Table 6- Results of ANOVA among work tasks of milking methods with reference to LCG classification

Variable		Source of variance	Degree of freedom	MS	F
SLCG	Stanchion barn	Treatment	2	775.4	1715.3**
		Error	33	0.5	
	Tandem parlor	Treatment	2	4853.4	11719.3**
		Error	33	0.4	
CLCG	Stanchion barn	Treatment	2	20642.7	21857.0**
		Error	33	0.9	
	Tandem parlor	Treatment	2	16151.0	5580.9**
		Error	33	2.9	
OLCG	Stanchion barn	Treatment	2	29683.7	21808.4**
		Error	33	1.4	
	Tandem parlor	Treatment	2	21732.2	14685.9**
		Error	33	1.480	

Note: ** refer to significant differences at level of 0.01.

Table 7- Proportions (%) of the direction of load carriage in comparison with the force of gravity based on work tasks' cycle times*

		Work tasks								
		Washing the teats		Attaching the cluster			Detaching the cluster			
Stanchion barn	Proportion	100%		16%	3%	81%	11%	6%	71%	12%
	Direction of load carriage in the order of appearance	→		↓	→	↑	↑	↓	→	↑
Tandem parlor	Proportion	11%	89%	16%	19%	65%	50%	35%	15%	
	Directionof load carriage in the order of appearance	↑	→	→	↑	↑	↑	↓	→	

*Legend:↓ ,↑ and → refer to similar, converse, and orthogonal LCGs (SLCG, CLCG, and OLCG) respectively.

In both milking methods, physiological strains (except RPE) for attaching the cluster were found to be higher than detaching the cluster. Based on the aforementioned studies, the increase in these indexes may be partly affected by the gravity effects (the mass of clusters). In attaching the cluster, the worker expended a considerable physiological effort to maintain the cluster at a constant height by applying the force converse of gravity with one hand. Simultaneously, the other hand was occupied to install the cluster's liners on the teats. This occupied a major proportion of cycle time in attaching the cluster in stanchion barns (81%) and tandem parlor (65%) (Table 7). In both methods, during detaching the cluster, the worker maintained the cluster with one hand and uninstalled the liners with another hand. This also induced applying the force converse of gravity to maintain the cluster. According to Table 7, proportions shown for uninstalling liners were lower than those of installing the liners in both stanchion barns (81%>11%) and tandem parlor (65%>50%). It could be the main reason for the increase in physiological strains in attaching the cluster compared with detaching the cluster in both methods.

The comparison between milking methods could address the effect of the workplace. The workplace design of the tandem parlor had major differences from that of the stanchion barn. The height level of the cluster hook was lower than cow teats in the tandem parlors, whereas, the inverse of this condition was established in the stanchion barn (Fig.1). Therefore, the workplace design of the tandem parlor induced the worker to carry the cluster from its hook (16%) and lift it to a higher level (cow teats) by applying a force converse of gravity (19%). But in stanchion barn worker carried it while changing his posture from stooping to squatting (declining work height, 16%) and moved it toward cow teats at the same height level (3%). These, in addition to installing cluster's liners (81% and 65% in stanchion barn and tandem parlor respectively), implied that during attaching the cluster, workers bore higher physiological strains in tandem parlor compared with stanchion barn.

Although, detaching the cluster was partly performed in an inverse order compared with attaching the cluster, LCGs of this operation were not in the inverse order of that of attaching the cluster. In the stanchion barn, in the work task of detaching the cluster, as shown in Table 7, the worker uninstalled the cluster's liners (11%), brought it down in a similar direction with gravity (6%), carried it toward milking machine (71%) and changed squatting posture to stooping posture to bring the cluster to the height level of the hook (12%). Uninstalling the cluster's liners in the tandem parlor (50%) induced to apply a more converse LCG (50%>11%+12). Then, the worker carried the cluster downward (35%) and toward hook (15%) in the tandem parlor. Results implied that perhaps the most important reason for the increase in physiological strains in tandem parlor compared with stanchion barn during detaching the cluster is more clearly expressed by considering the CLCG in the tandem parlor (50%) and stanchion barn (11%+12%=23%).

The present study showed "it is discussable that some factors, which have not been addressed yet, may affect physiological strains in dairy farms such as the force of gravity". Our study did not decide to generalize the effect of gravity as the absolute factor affecting physiological strains in all cases. Some other factors may also affect the physiological strains in dairy farm activities. For example, working posture is an important factor in the variation in physiological strains. In this case, former researchers reported that more walking was an explanation for increasing HR from women to men during milking (Perkiö-Mäkelä and Hentilä, 2005). The work habits of the worker may also contribute to the physiological strains in dairy farm activities, as a strong matter in ergonomic issues, which is not easily changed (Nevala-Puranen, 1995). Besides, the impact of any load is not just a function of its mass, but its dimensions and distribution around the body which could affect the body's center of gravity and finally affect physiological strains (Taylor *et al*., 2016). Overall, it could be said that probably several factors (e.g. gravity, working postures, and body's center of gravity) could simultaneously affect the human physiological strains in milking work tasks in dairy farms. Further studies would be undertaken to illuminate these cases.

Limitations

This study was undertaken by employing the male gender only. If women took part in this study, findings could be more generalizable.

Conclusion

The present study showed that by developing dairy farm mechanization from stanchion barn to tandem parlor, during cow milking, workers are induced to apply higher forces converse of gravity which causes higher human physiological strains as one of the occupational health challenges. It had been shown that the force of gravity affects human physiological strains. Simultaneously, other factors may also affect human physiological strains. Therefore, the mechanization of dairy farms should be developed not only for improving the rate of work and performance but also for making conditions toward a reduction in the use of human physical forces.

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References

1. Abe, D., S. Muraki, and A. Yasukouchi. 2008. Ergonomic effects of load carriage on energy cost of gradient walking. Applied Ergonomics 39: 144-149. https://doi.org/10.1016/j.apergo.2007.06.001.
2. Ahonen, E., J. M. Venäläinen, U. Könönen, and T. Klenk. 1990. The physical strain of dairy farming. Ergonomics 33: 1549-1555. https://doi.org/10.1080/00140139008925353.
3. Almassi, M., S. Kiani, and N. Loveimi. 2014. Principles of agricultural mechanization. Gofteman-e-Andishe-e-Mo'aser, Tehran, Iran. (In Persian).
4. Astrand, P. O., and K. Rodahl. 1986. Textbook of work physiology: physiological bases of exercise, 3rd ed. McGraw-Hill Book Company, New York.
5. Brubaker, C. E., C. A. McLaurin, and, I. S. McClay. 1986. Effects of side slope on wheelchair performance. Journal of Rehabilitation Research and Development 23: 55-58.
6. Cabral, L. L., F. Y. Nakamura, J. M. Stefanello, L. C. Pessoa, B. P. Smirmaul, and G. Pereira. 2020. Initial Validity and Reliability of the Portuguese Borg Rating of Perceived Exertion 6-20 Scale. Measurement in Physical Education and Exercise Science 24: 103-114. https://doi.org/10.1080/1091367X.2019.1710709.
7. Chang, Y. K., B. L. Alderman, C. H. Chu, T. M. Hung, and J. H. Liu. 2020. Conducting exercise trials for obese adolescents within the effectiveness setting: A response with commentary to Ejima *et al*. (2019). Psychology of Sport and Exercise 46: 101605. https://doi.org/10.1016/j.psychsport.2019.101605.
8. Claessen, G., A. La Gerche, A. Van De Bruaene, M. Claeys, R. Willems, S. Dymarkowski, J. Bogaert, P. Claus, W. Budts, H. Heidbuchel, and M. Gewillig. 2019. Heart rate reserve in fontan patients: chrono tropic incompetence or hemodynamic limitation? Journal of the American Heart Association 8: e012008. DOI: 10.1161/JAHA.119.012008.
9. Garzon, M., and A. S. Comtois. 2020. Discussion of "Concurrent and Construct Validation of a Scale for Rating Perceived Exertion in Aquatic Cycling for Young Men". Journal of Sports Science & Medicine 19: 231-234.
10. Gholami, H., D. Kalantari, and M. Rajabi Vandechali. 2017. Ergonomic Evaluation of Vibrations of a Rototiller with New Blade. Journal of Agricultural Machinery 7: 491-502. DOI: 10.22067/jam.v7i2.56061. (In Persian).
11. Gordon, M. J., B. R. Goslin, T. Graham, and J. Hoare. 1983. Comparison between load carriage and grade walking on a treadmill. Ergonomics 26: 289-298. DOI: 10.1080/00140138308963342.
12. Hasantabar, S., S. R. M. Seyedi, and D. Kalantari. 2019. Construction of a seed pod husker and evaluating with soybean in laboratory scale. Journal of Agricultural Machinery 9: 15-29. DOI: 10.22067/jam.v9i1.66218. (In Persian).

13. Hayati, A., A. Marzban, and M. Leylizadeh. 2018a. Discovering the physical onerous activities in manual sesame grain harvest using postural analysis. Agricultural Engineering International: CIGR Journal 20: 126-131.
14. Hayati, A., A., Marzban, and M. A. Asoodar. 2015a. Ergonomic assessment of hand cow milking operations in Khuzestan province of Iran. Agricultural Engineering International: CIGR Journal 17: 140-145.
15. Hayati, A., A., Marzban, and M. A. Asoodar. 2015b. Ergonomic evaluation of hand and mechanized milking in dairy farms. Iranian Journal of Ergonomics 3: 65-75. (In Persian).
16. Hayati, A., A., Marzban, and M. A. Asoodar. 2018b. Evaluation of performance and cost of hand and mechanized cow milking methods. Iranian Journal of Biosystems Engineering 49: 27-34. DOI: 10.22059/ijbse.2017.138776.664695. (In Persian).
17. Jakob, M. C., and J. Rosecrance, 2018. International perspectives on health and safety among dairy workers: challenges, solutions and the future. Frontiers in Public Health, London.
18. Javidi Gharacheh, M., and M. Khojastehpour. 2016. Ergonomic evaluation of tea farmers in north of Iran during plucking using body modeling. Journal of Agricultural Machinery 6: 488-498. (In Persian).
19. Lowe, B. D., P. G. Dempsey, and E. M. Jones. 2019. Ergonomics assessment methods used by ergonomics professionals. Applied Ergonomics 81, 102882. https://doi.org/10.1016/j.apergo.2019.102882.
20. Malhotra, M. S., and J. S. Gupta. 1965. Carrying of school bags by children. Ergonomics 8: 55-60. https://doi.org/10.1080/00140136508930774.
21. Manjarres, J., P. Narvaez, K. Gasser, W. Percybrooks, and M. Pardo. 2020. Physical workload tracking using human activity recognition with wearable devices. Sensors 20: 39. https://doi.org/10.3390/s20010039.
22. Marzban, A., and A. Hayati. 2018. Ergonomic evaluation of traditional date fruit harvesting. Iranian Journal of Ergonomics 6: 11-20. DOI: 10.30699/jergon.6.3.2. (In Persian).
23. Minetti, A. E., C. Moia, G. S. Roi, D. Susta, and G. Ferretti, 2002. Energy cost of walking and running at extreme uphill and downhill slopes. Journal of Applied Physiology 93: 1039-1046. https://doi.org/10.1152/japplphysiol.01177.2001.
24. Montes, J., and J. W. Navalta. 2019. Reliability of the Polar T31 Uncoded Heart Rate Monitor in Free Motion and Treadmill Activities. International Journal of Exercise Science 12: 69-76.
25. Nemeth, G., U. P. Arborelius, O. K. Svensson, and R. Nisell, 1990. The load on the low back and hips and muscular activity during machine milking. International Journal of Industrial Ergonomics 5: 115-123. https://doi.org/10.1016/0169-8141(90)90002-J.
26. Nevala-Puranen, N. 1995. Reduction of farmers' postural load during occupationally oriented medical rehabilitation. Applied Ergonomics 26: 411-415. https://doi.org/10.1016/0003-6870(95)00027-5.
27. Penko, A. L., J. E. Barkley, M. M. Koop, and J. L. Alberts. 2017. Borg scale is valid for ratings of perceived exertion for individuals with Parkinson’s disease. International Journal of Exercise Science 10: 76.
28. Perkiö-Mäkelä, M., and H. Hentilä. 2005. Physical work strain of dairy farming in loose housing barns. International Journal of Industrial Ergonomics 35: 57-65. https://doi.org/10.1016/j.ergon.2004.08.004.
29. Pizzol, D., L. Smith, L. Fontana, M. G. Caruso, A. Bertoldo, J. Demurtas, D. McDermott, A. Garolla, I. Grabovac, and N. Veronese. 2020. Associations between body mass index, waist circumference and erectile dysfunction: a systematic review and META-analysis. Reviews in Endocrine and Metabolic Disorders. https://doi.org/10.1007/s11154-020-09541-0.

30. Póvoas, S., P. Krustrup, and C. Castagna. 2020. Estimation of maximal heart rate in recreational football: a field study. European Journal of Applied Physiology 120: 925-933. https://doi.org/10.1007/s00421-020-04334-4.
31. Puckett, H. B. 1980. Mechanization of livestock production in the United States. BSAP Occasional Publication 2: 191-204. https://doi.org/10.1017/S0263967X00000380.
32. Rostami, M. A., A. Gavadi, M. Heidari Soltanabadi, A. Mehdinia, and M. Shaker. 2015. Ergonomic assessment of some commonly used tractors in Iran. Journal of Agricultural Machinery 5: 456-467. (In Persian).
33. Simpson, K. M., B. J. Munro, and J. R. Steele. 2011. Effect of load mass on posture, heart rate and subjective responses of recreational female hikers to prolonged load carriage. Applied Ergonomics 42: 403-410. https://doi.org/10.1016/j.apergo.2010.08.018.
34. Taylor, N. A., G. E. Peoples, and S. R. Petersen. 2016. Load carriage, human performance, and employment standards. Applied Physiology, Nutrition, and Metabolism 41: S131-S147. dx.doi.org/10.1139/apnm-2015-0486.
35. Vos, H. W. 1974. Some ergonomic aspects of parlour milking. Canadian Agricultural Engineering 16: 45-48. https://doi.org/10.3168/jds.2014-8535.
36. Williams, N. 2017. The Borg rating of perceived exertion (RPE) scale. Occupational Medicine 67: 404-405. https://doi.org/10.1093/occmed/kqx063.

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مقاله پژوهشی

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مقایسه فشارهای فیزیولوژیکی انسانی در دو روش مکانیزه شیردوشی گاو شیری با تأکید بر محیط کار و گرانش زمین

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چکیده

با وجود توسعه مکانیزاسیون دامداری‌های گاو شیری، هنوز هم فعالیت‌های شیردوشی همراه با فشارهای کاری سنگین می‌باشد که باعث بروز فشارهای فیزیولوژیکی روی نیروی کار می‌شود. در این مطالعه نقش نیروی گرانش در ارتباط بین حمل بار و فشارهای فیزیولوژیکی در وظایف کاری دو سیستم عمده شیردوشی گاو شیری شامل شیردوشی در جایگاه‌های استانشیون و سالن‌های تاندم مورد بررسی قرار گرفت. این دو روش به‌طور مشابه شامل سه وظیفه کاری شستن پستان‌های گاو، وصل کردن خرچنگی شیردوش و جداکردن آن بود. انرژی مصرفی انسانی برآورد شد و راستای حمل بار در مقایسه با نیروی گرانش مورد ملاحظه قرار گرفت. بیست و چهار کارگر در این مطالعه شرکت کردند. بالاترین ضربان قلب (۱۰۷ ضربه بر دقیقه) و بالاترین میزان مصرف انرژی انسانی (۳۳/۵ کیلوژول بر دقیقه) برای وظیفه کاری وصل کردن خرچنگی شیردوش در روش شیردوشی در سالن‌های تاندم گزارش شد. در کل، این روش در مقایسه با روش شیردوشی استانشیون باعث اعمال فشارهای فیزیولوژیکی بالاتری شد و نسبت بالاتری از حمل بارهایی که در این روش استفاده شد در خلاف جهت گرانش بود. با توسعه مکانیزاسیون دامداری‌های گاو شیری از ایستگاه‌های استانشیون به سمت سالن‌های تاندم، کارگران شیردوشی به سمت اعمال نیروهای بیشتری در خلاف جهت نیروی گرانشی سوق داده می‌شوند که این باعث بالا رفتن فشارهای فیزیولوژی وارد بر کارگر می‌شود. در توسعه مکانیزاسیون دامداری‌های گاو شیری نه تنها می‌بایست بهبود سرعت کار و عملکرد را مد نظر قرار داد بلکه باید شرایط را به گونه‌ای فراهم کرد که باعث کمتر شدن استفاده از توان فیزیکی نیروی کار شود.

واژه‌های کلیدی: انرژی مصرفی، حمل بار، شیردوشی استانشیون، شیردوشی سالنی تاندم

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