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Assessment of static loads on the locomotion system accompanying work on dairy stock farms

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ABSTRACT

Aim. The aim of this study was to perform statistical analyses of the load on the locomotion system during a variety of basic (elementary) work tasks associated with dairy cattle breeding, its causes and suggested key preventive measures illustrated, with an example of a large dairy stock farm.

Materials and methods. A comparative analysis was performed to compare the activities of the locomotion system during the use of traditional and modern milking methods. The analysis included elementary work tasks performed by 12 healthy, full-time stock workers (only males) employed at a large dairy stock farm in the Province of Wielkopolska, operating as a limited liability company. The working area consisted of two dairy cowsheds, in which different milking methods were used. OWAS (Ovako Working Posture Analysing System) method and the supporting WinOWAS computer system were employed to analyse all occupational activities generating static loads.

Conclusions. The elementary work tasks in dairy cow breeding may involve significant loads on the musculoskeletal system. Unergonomic performance of these tasks results from bad habits and the level of mechanisation specific to a dairy cowshed. The proposed corrective and preventive measures presented in the analysis of specific works consists mainly in substituting the tools used so far with more ergonomic equipment, which is safer for the human locomotion system. The implementation of the proposed solutions requires specific investments; however, the risk of locomotor system disorders can be significantly reduced. Specific works, especially in traditional cowsheds, such as cow preparation for milking and the milking process itself, require prompt corrective measures, however, the lack of space may seriously limit the possibility to implement such measures, and stock workers are forced to assume awkward body positions. Education of stock farm staff should become one of the key preventive measures. Educational campaigns should be introduced within the framework of obligatory occupational safety training, in particular. However, the access to occupational safety training among individual farmers in Poland is currently very limited and may pose a challenge.

Keywords: static loads, OWAS, dairy stock farms, musculoskeletal system.

Introduction

In the majority of occupational conditions in agriculture, the locomotion system is exposed to specific loads [7, 9, 13–15, 17–20, 31], such as physical effort to compensate static load, which may negatively affect general health, and the locomotion system in particular [2, 13, 26, 30, 35, 40–44]. The operation of milking equipment is another risk factor for injuring the wrists and hands [38]. Typical working activities in agriculture, especially activities associated with the breeding of dairy cattle, constitute major risk factors for low back pain (bending, twisting, manual material handling and exposure to whole-body vibrations, etc.), neck and shoulders symptoms (especially monotonous and repetitive work) and osteoarthritis of the hip and the knee (proposed as a contributing factor) [1, 6, 21, 27, 29, 32, 35, 41, 46]. The outcomes of previous studies show that pre-milking, attaching and drying (cleaning the udder with a towel) were the most physically demanding milking tasks for the wrists and hands [27, 32, 38]. Another major problem mentioned in the available literature is the effect of technical equipment in breeding and milking premises on the level of physical load the locomotion system is exposed to in individuals working with dairy cattle [2, 32, 37, 38].

Aim

The aim of this study was to perform statistical analyses of the load on the locomotion system during a variety of basic (elementary) work tasks associated with dairy cattle breeding, its causes and suggested key preventive measures illustrated with an example of a large dairy stock farm. A comparative analysis was performed to compare the activities of the locomotion system during the use of traditional and modern milking methods.

Materials and methods

The analysis included elementary work tasks performed by 12 healthy, full-time stock workers (only males) employed at a large dairy stock farm in the Province of Wielkopolska, operating as a limited liability company. Their mean age was 41 years (range 24–49) and their median height and weight were 173 cm (range 158–180) and 79 kg (range 59–87), respectively. All workers were right handed. Each worker was recorded during the entire duration of elementary work tasks. The working area consisted of two dairy cowsheds, in which different milking methods were used. OWAS (Ovako Working Posture Analysing System) method and the supporting WinOWAS computer system were employed to analyse all occupational activities generating static loads [45]. This software is available for free online [45]. The OWAS method has been used quite commonly and offers clearly specified operating procedures, hence the analysis outcomes are easier to discuss and extrapolate as compared to the outcomes of the author's own research methods [4, 5, 10, 12, 16, 22–25, 36]. In order for the presented outcomes to be as universal as possible, the total daily and weekly timing of the performed activities was excluded from analysis, and the analysis was focused predominantly on the assessment of static loads during the so-called elementary work tasks. Note that the total risk assessment of locomotor system complaints may differ depending on the total time devoted to the performance of specific elementary work tasks (note that the majority of Polish farms are privately owned, and the number of working hours differs significantly from one farm to another).

The study materials (video recordings) were registered by means of a video camera on site, and were later used in further analyses. The stock workers were video recorded performing specific elementary tasks composed of specific activity cycles. Whenever a single activity within the framework of a specific task was difficult to separate and to record (whenever specific activities involved frequent changes in the position of particular parts of the body), several activity cycles were analysed together. This was done to generate averaged, real study results.

The study algorithm of the OWAS method consists of:

- video recording of a working cycle (work task),
- analysis of the video recordings, consisting in the assessment of baseline body position and external load (which was classified and assigned a specific code according to the OWAS notation, **Table 1**) and subsequent assessments of each change in a specific body part position (upper and lower extremities, trunk) and the level of external load. The evaluation outcomes are reported in a standard report form

Table 1. Categories of static load size according to OWAS [45]

Category	Description
1	– natural position/s during work – optimum or acceptable load – no changes are required at the workstation
2	– position/s during work may negatively affect the musculoskeletal system – loads close to acceptable – there is no need for immediate changes at workstation, however, they need to be considered in the near future
3	– position/s during work negatively affect the musculoskeletal system – high loads – changes at workstation need to be introduced as soon as possible
4	– position/s during work have a powerful negative effect on the musculoskeletal system – very high loads – changes at workstation need to be introduced immediately

– data from report forms (separate for each work task) entered in WinOWAS. On the basis of data entered in WinOWAS, the software generates a collective list of codes for the observed body positions, which are assigned to specific postural load categories (**Table 1**). The percentage share of the analysed work tasks assigned to the respective categories reflects the level of static load during specific elementary work task, and may be used in further analyses of the total risk of musculoskeletal complaints when performing a series of elementary work tasks throughout a working day. The analysis outcomes are also presented graphically as diagrams of loads on specific body parts and the share of each category in the total workload in the course of elementary work tasks (these data were omitted as too elaborate). These data were sufficient to determine, which elementary work tasks involved high peak static loads and to specify body parts most exposed. On the basis of the study outcomes, specific body postures were determined as preventive measures, to be introduced in conjunction with applied corrective ergonomics.

RESULTS

During a typical working day, the following 9 elementary work tasks were observed and video recorded:

– manual removal of manure from cow stalls,
– removal of manure from the dairy cowshed with a farm tractor equipped with fore loader,
– cleaning of cow stalls with a pressure washer,
– manual spread of litter,
– manual sweeping of feed in the dairy cowshed,
– cow preparation before milking in a traditional dairy cowshed – udder hygiene,
– preparation of cows before milking in a traditional dairy cowshed – milk sampling,
– milking in a traditional dairy cowshed,
– milking in a new dairy cowshed,

The work tasks were selected based on the criteria of significance and autonomy. As a result, the analysis included elementary work tasks routinely performed by stock workers that consumed the majority of working time, and on the other hand – tasks that were significantly distinct. For example, in terms of static load, the removal of manure with a farm tractor is similar to feed supply with a tractor drawn feed carrier. Hence, detailed analysis included only activities performed in the course of manure removal, however, the analysis results reveal musculoskeletal load typical for both tasks. These similarities were indicated in the description of specific elementary work tasks.

Elementary work tasks

*Manual removal of manure from cow stalls (**Figure 1, 2**)*

This work task consisted in the removal and scraping of manure from cow stalls to a 10-cm deep and 80 cm wide manure passage adjacent to cow stalls. Manure was removed with a fork. Stock workers were video recorded when performing this task at 5 adjacent stalls. During the entire working day, a single stock worker removed manure from app. 40 similar cow stalls. In the course of manure removal by 3 stock workers, 22 changes in body positions or loads were observed (22 changes against 23 body positions).

Figure 1. One of body positions during manual manure removal from cow stalls

Figure 2. Another body position during manual manure removal from cow stalls

Related tasks included the collection and relocation of manure remaining after the passage of a tractor that removes the manure onto a heap or that loads the manure from the heap to a trailer or manure spreader. The analysis of video recordings revealed that the stock workers spent as much as 17% of their working time in body positions assigned to Category 4, which involves significant static load on the locomotor system, especially working with the trunk bent and/or twisted and/or with the weight of the body resting on one bent leg (even if the additional external load is limited). These body positions require prompt corrective measures. Also, various body positions assigned to Category 3 put a significant strain on the locomotor system and may cause lasting disorders if performed on a regular basis. In terms of specific body parts, manual manure removal involves significant loads on the trunk (as much as 35% of the working time is spent in bent and twisted body position, which is a major risk factor of lumbar spine disorders). Lower extremities are also severely strained, especially when the task is performed on one bent leg.

Removal of manure from dairy cowshed using a tractor with loader

This elementary task consisted in the removal of manure when driving along the manure passage with a farm tractor URSUS C-360 equipped with a fore loader TUR-2. This task can be divided into the following activities: removal of manure from the cow shed, manure storage outside the cow house on a manure slab, and driving the vehicle backwards back into the cow shed. Specific isolated activities were unrelated to specific distribution of isolated loads; therefore the analysis included all recordings. The duration of a single complete analysed activity cycle was 1 minute 8 sec on average, and involved 17 changes in the position of body parts.

The analysis of video recordings revealed no body positions assigned to Category 3 and 4, which means that the static load in the course of this elementary work task was relatively low. The analysed activities were done in a sitting position, and the value of additional forces did not exceed 100 N, so the stock worker's body position was assigned to Category 2 due to awkward positions of the trunk (bent, or with the lumbar or (additionally) cervical spine simultaneously bent and twisted, especially when driving backwards). In addition, stock workers are exposed to whole-body vibrations, which is a risk factor for lumbo-sacral spine disorders. The related tasks may include feed preparation using a feed carrier and driving a feed carrier along the cow house.

Figure 3. One of body positions during stall cleaning

Cleaning of cow stalls

This elementary work task consisted in the cleaning of cow stalls using Kärcher high-pressure washer. Stock workers were wearing wellingtons and waterproof overalls, and were controlling a washing pipe held in their hands and directed a stream of liquid to manure and litter remaining in the stalls. The aim of this task was to clean the cow stalls and to provide conditions for subsequent disinfection of the premises using chemical agents. The cleaning process of 2 stalls was video recorded, which took 1 minute and 34 seconds on average when performed by a single stock worker. During this time, 20 changes in the position of body parts were observed. In the course of this elementary task, objects up to 10 kg were carried by the stock workers. The analysis of video recordings revealed no body positions assigned to Category 3 and 4, which means that this elementary work task (cleaning the cow stalls with a pressure washer) involved no significant static load. However, over 3/4 of all body positions were assigned to Category 2 in terms of the static load as the stock worker's trunk was frequently bent forward, or simultaneously bent and twisted. There were two body positions when the stock workers were required to maintain one arm above the acromion (**Figure 3**). Related work tasks included floor cleaning in the milking parlour or work related to room disinfection.

Figure 4. One of body positions during litter spreading

Figure 5. Another body position during litter spreading

Figure 6. Another body position during litter spreading

*Spreading of litter (**Figures 4, 5, 6**)*

This elementary work task consisted in manual placing of litter in stalls using a fork. This task comprised the following activities: collecting straw from a bale, removal of straw to a cow stall typically located at a 10 m distance, litter spread in the cow stall. 5 cow stalls were video recorded, and each stock worker was typically in charge of 40 cow stalls per each working day. In the analysis of video recordings, 22 changes in the body position and load during this elementary work task were identified (the load meaning also the value of force used, for example, when the fork was inserted into a layer of baled straw).

As evidenced in the number of body positions assigned to the relevant categories, this elementary work task involved a considerable static load. Approximately 13% of the time devoted to this task accounted for body positions assigned to Category 4. As much as nearly ¼ of this time was spent in positions assigned to Category 3 (which may be also harmful). The collection of straw from a bale put the most static strain on the stock worker. Straw was collected on bent knees, and simultaneously bent and twisted trunk. Note that straw can be quite heavy when wet or tightly baled. As already mentioned, the peak static load is put on the trunk during this particular task (workers usually lean forward, or bend and twist the trunk, which involves high risk of injury).

*Manual sweeping of feed in the dairy cowshed (**Figure 7**)*

This elementary work task consisted in the handling and sweeping of feed in a feeding passage in the direction of cow stalls, using a 460 x 360 mm shovel. The feed was prepared in a feed wagon and consisted of a homogenous mixture. This elementary work task was done at approximately 80 cow stalls per one stockworker per day. Stock workers performing this task were video recorded at 5 different cow stalls. As many as 33 changes in the positions of body parts or the external load values were identified. This task was very dynamic with frequent changes of body positions and sinusoidal distribution of loads (empty shovel-full shovel).

Approximately 1/2 of all body positions and loads during this work task were assigned to Category 3 and 4. These body postures require prompt corrective measures. Only 9% of body postures were assigned to Category 1. The highest strain was put on lower extremities during this particular elementary work task, as 44% of the time devoted to this task was completed on bent legs (the time interval when stock workers were holding a full shovel). The bent legs 'supported'

Figure 7. One of body positions during manual feed sweeping

the upper extremities. Workers found it easier to carry the load on and in front of the shovel while holding the legs bent. For over 90% of time, stock workers held their trunks bent forward, and simultaneously bent and twisted the trunk for as long as 1/3 of the time devoted to this task. Related tasks included manual loading activities, such as the removal of the remaining silage from the storage bins.

Cow preparation before milking in a traditional dairy cowshed – udder hygiene

This elementary work task consisted in udder cleaning with a cloth soaked in water with an addition of antiseptic agent before milking. This task was performed in a traditional cow shed with no milking parlour pit. Stock workers, who performed this task were squatting or kneeling in order to reach the udder. Apart from the cloth, stock workers needed to have 2 buckets, 10 l vol. each, filled with water solution with an addition of antiseptic preparation. There were two milking procedures performed each day. There were approximately 240 cows in the analysed cowshed, which means that the milking process was repeated 480 times every day. 4 stock workers were responsible for pre-milking udder hygiene, which means that each stock worker needed to clean 120 cows every day. The cleaning process took 2 minutes and 10 seconds on average to complete. 24 changes in the body parts were observed during this elementary work task. This task was mainly done at less than 10 kg load. Only when stockworkers carried buckets with water, the external load equalled app. 18 kg.

The number of body positions and the accompanying loads assigned to specific categories was similar, which means that the share of harmful activities assigned to Category 3 and 4 was significant. The activities assigned to Category 4 included body postures with the pectoral and lumbo-sacral spine simultaneously bent forward and twisted. Stockworkers were keeping their legs bent or were kneeling on one or both knees. In the latter case, the stockworker's body position was qualified to Category 3, as the static load was slightly lower, but still significant. In the position assigned to Category 3, the trunk was bent forward and one of the arms was raised above the shoulder joint. Related task consisted in applying an ointment on the udder in case of inflammation.

*Collecting milk samples in a traditional dairy cowshed (**Figure 8**)*

This elementary work task consisted in collecting milk samples from 4 teats onto a stand with 4 separate fields. The samples were collected from each cow to verify if the milk was fit for consumption and to prevent mixing high-quality milk with milk found unfit for consumption. Samples were collected by 2 stockworkers per cow house, and each stockworker was required to collect 240 milk samples per day. Stock workers performing this task were video recorded when collecting samples from 5 cows, and the task took approximately 1 minute and 10 seconds to complete. 9 changes in body position were observed in each stock worker;

Figure 8. One of body positions during cow preparation before milking in a traditional type of cowshed – udder hygiene

external load remained below 10 kg. Stock workers performing this task needed to collect samples on a tray and add a preparation to each sample to determine if the milk was fit for consumption. It was found that 1/5 of the time devoted to this task was performed in harmful body positions assigned to Category 3 and 4, since the lumbar spine was simultaneously bent forward and twisted (similarly to the previous task), and stockworkers were forced to squat or kneel.

Milking in a traditional dairy cowshed

This elementary task consisted in cow milking in a traditional cowshed (240 dairy cows). Each stock worker tended to approximately 60 cows, and was required to milk about 120 cows each working day. This work task comprised the following activities: connecting the milking apparatus to the vacuum and milk pipelines, milking, closing each teat with an infection prevention agent, removing the milking apparatus and relocating it to the adjacent stall. Stock workers were video recorded milking a single cow. It took 1 minute and 42 seconds on average to complete the entire milking procedure. During this time, 14 changes in the position of body parts were observed. External load during the milking procedure did not exceed 10 kg as the milk was transported via milk pipe directly to containers. In dairy cowsheds – mainly smaller ones – the milk is collected to containers that are later removed and emptied to the main container. Stock workers are then required to carry significant weights (as high as 20–25 kg). This was not the case in the analysed cowshed.

Milking is another elementary work task in a traditional cowshed, which requires the stock workers to squat or kneel, and to simultaneously bend forward and twist the trunk, which involves considerable static load. These body positions accounted for approximately 20% of the total time devoted to this particular task. Moreover, another 20% of the time was spent with the trunk bent forward and twisted. The highest strain was put on the lower extremities when bending legs or changing body position to squating (when connecting and disconnecting the milking apparatus and when closing the teats). The milking process itself was when the static load on the musculoskeletal system was reduced and stock workers remained in a standing position when the milking process was proceeding for several dozens of seconds.

*Milking in a new dairy cowshed (**Figure 9**)*

This elementary work task consisted in performing a milking procedure in a milking parlour in a new type of dairy cowshed. The parlour is equipped with 30 milking stalls in two rows, with 15 cows each. Animals are standing next to each other, turned backwards to the passage. Teats are located at the level of sight of the stock workers, who attach the milking equipment to the teats. Stock workers are no longer required to squat or kneel and the highest static loads typical for traditional cowsheds are eliminated. In the analysed farm, the milking passage was worked by 2 stock workers simultaneously. The stock workers were equipped with 3 milking units, which they carried from one side of the milking passage to another. This saved time, as several cows were milked simultaneously. The activities included in this task were similar to the milking operations performed in a traditional cowshed. Apart from connecting, disconnecting and handling the milking equipment, stock workers also covered the teats with an infection prevention agent.

Figure 9. One of body positions during cow preparation before milking in a modern type of cow shed

The working cycle lasted 34 seconds per one cow on average. Within 34 seconds, stock workers changed their body position as many as 38 times. Similarly to milking cows in a traditional cowshed, stock workers were also exposed to external loads, as they had to carry the milking units that weighted less than 10 kg.

The static load was significantly reduced as the squating and kneeling positions were eliminated. None of the body positions was assigned to Category 3 or 4. Moreover, stock workers spent half of the milking time in body positions qualified to Category 1, which were safe and required no corrective measures.

With reference to specific body parts, it was difficult to point out any parts of the body, which were particularly exposed to loads. The trunk was bent for 38% of the working time. In case of upper extremities – one arm was raised above the acronym. Lower extremities were exposed to a slight static load, as the stockworkers were standing on straight legs. Positions with slightly bent legs and squatting were eliminated.

Stock workers habitually assumed a variety of inappropriate body positions in order to be more 'comfortable' at work, which means they were unaware of the associated risks. Inappropriate body postures typically included:

- driving a tractor when removing manure with the trunk bent forward – stock workers should sit straight and lean against the seat,
- turning the head while driving a tractor instead of using rear-view mirrors, which is strenuous for the trunk and cervical spine,
- resting the weight of the body on a single leg only under an additional external load – when removing manure with a fork,
- bending of lower extremities when loading (too much load is carried on tools, legs support the arms, as during manual sweeping of feed),
- moving the milking unit in a traditional cowshed with one arm only held above the acromion.

Discussion

In 6 out of 9 of the analysed elementary work tasks, high and very high static load were identified. The assessment of loads put on particular body parts during work in a traditional dairy cowshed proved what has already been known – the high peak static load is placed on the trunk when simultaneously bent and twisted [23, 24]. Lower extremities are also exposed to significant strain, since stock workers need to squat or kneel when they perform their work on single-level working stands. To maintain balance, stock workers need to rest their hand against the animal and raise their arms above the acromion. This is when the shoulder joint is particularly strained. The outcomes of this study confirm the results of previous alarming analyses presented by other researchers concerning static spinal loads [23, 45]. Moreover, this study confirms the conclusions of previous analyses, which showed that milking in the traditional tethering system was associated with higher peak load for the forearm and biceps muscles than milking in the modern systems [32, 38]. The problem consists of the majority of hazardous body postures being forced body positions. Workers are forced to assume specific body postures during work as the buildings, rooms and appliances for livestock rearing have been designed without any consideration for basic ergonomics [23]. This is particularly evident when the milking methods are compared in traditional and modern dairy cowsheds. In modern livestock rearing facilities, stock workers are not forced to squat or knee, bent forward or hold their trunk twisted, and are exposed to slight static loads only; the same task performed in a traditional cowshed involves significant static loads for over 1/4 of the time spent on performing specific work tasks, and the body position of stock workers requires prompt corrective measures [23, 45].

Key corrective measures:

- Manual removal of manure – replace manual manure removal with a mechanical system; stock workers need to be informed of the risk associated with assuming incorrect body position.
- Cleaning of cow stalls – stock workers need to be informed of the necessity to keep their body straight and to adjust the wash pipe length of the washer to the height and arm's reach of individual stock workers.
- Spreading of litter – introduce specific mechanisms with straw shredder and introduce new habits among stock workers to limit static loads. Workers should avoid bending their legs during work. When the working time with bent legs exceeds 30% of the total working time, the musculoskeletal system is severely affected and corrective measures should be promptly introduced [23, 45].
- Manual feed sweeping – note that the feed passage dimensions at the evaluated workstation allow for the manual feed reloading to be supplemented with a mechanical sweeper (such as a scraper fixed to the front of the tractor or a horizontal sweep auger).
- Udder hygiene and milk sampling – both tasks involve forced body postures. This may be attributed to the design of the workstations, as the stock workers are forced to assume specific body positions to collect a milk sample on a tray, etc. The only solution is to use modern milking methods [2].

The outcome of this study suggests that there is a serious deficiency in the knowledge of basic ergonomic principles for performing physical work among stock workers. Suitable training and the use of kinetic-therapeutic methods may contribute to the limiting the consequences of unergonomic postural loads [3, 11, 28, 33].

Note that a specific share of work in Polish stock farms is performed by women. The consequences of unergonomic positions are particularly noticeable in women [5, 39].

To conclude, the OWAS method may be considered a valuable tool in assessing the static load in dairy cow breeding. However, changeable daily and weekly working times devoted to elementary work tasks may be problematic, as it may be difficult to assess the real risk resulting from such loads on the musculoskeletal system.

Conclusions

1. The elementary work tasks in dairy cow breeding may involve significant loads on the musculoskeletal system. Unergonomic performance of these tasks results from bad habits and the level of mechanisation specific to a dairy cowshed. Consequently, stock workers are forced to assume more or less ergonomic body positions.
2. The proposed corrective and preventive measures presented in the analysis of specific works consists mainly in substituting the tools used so far with more ergonomic equipment, which is safer for the human locomotion system. The implementation of the proposed solutions requires specific investments; however, the risk of locomotor system disorders can be significantly reduced.
3. Specific works, especially in traditional cowsheds, such as cow preparation for milking and the milking process itself, require prompt corrective measures, however, the lack of space may seriously limit the possibility to implement such measures, and stock workers are forced to assume awkward body positions.
4. Education of stock farm staff should become one of the key preventive measures. Educational campaigns should be introduced within the framework of obligatory occupational safety training, in particular. However, the access to occupational safety training among individual farmers in Poland is currently very limited and may pose a challenge.
5. A variety of activities in dairy cow breeding in Poland are performed by women. The consequences of working in unergonomic positions caused by insufficient education and poor technical equipment may be particularly noticeable in women.
6. Further detailed analyses are recommended concerning the loads on the locomotor system and the time devoted to specific tasks, in order to evaluate the actual risk of locomotive disorders in a variety of working circumstances and working conditions in the sector of dairy cow breeding, considering the specific conditions prevailing on stock farms in Poland.

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Conflict of interest statement
The authors declare no conflict of interest.

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References

1. Bigos SJ, Battie MC, Sprengler DM, Fisher LD, Fordyce WE, Hansson TH, Nachemson AL, Wortley MD. A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine. 1991;16:1–6.
2. Bijl R, Kooistra SR, Hogeveen H. The profitability of automatic milking on Dutch dairy farms. J Dairy Sci. 2007;90:239–248.
3. Bilski B, Bednarek A. Disorders of locomotor system and efficiacy of physiotherapy in coal miners. Med Pr. 2003;54:503–509.
4. Bilski B, Kandefer W. Determinants of the locomotor system load and their health effects among midwives. Med Pr. 2007;58:7–12.
5. Bilski B, Sykutera L. Determinants of musculoskeletal system load and their health effects among nurses from four Poznan hospitals. Med Pr. 2004;55:411–416.
6. Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders. Scand J Work Environ Health. 1997;23:243–256.
7. Davis KG, Kotowski SE. Understanding the ergonomic risk for musculoskeletal disorders in the United States agricultural sector. Am J Ind Med. 2007 50:501–511.
8. de Bruijn I, Engels JA, van der Gulden JW. A simple method to evaluate the reliability of OWAS observations. Appl Ergon. 1998;29:281–283.
9. Douphrate DI, Rosecrance JC, Stallones L, Reynolds SJ, Gilkey DP. Livestock-handling injuries in agriculture: an analysis of Colorado workers' compensation data. Am J Ind Med. 2009;52:391–407.
10. Engels JA, Landeweerd JA, Kant Y. An OWAS-based analysis of nurses' working postures. Ergonomics. 1994 37:909–919.
11. Engels JA, van der Gulden JW, Senden TF, Kolk JJ, Binkhorst RA. The effects of an ergonomic-educational course. Postural load, perceived physical exertion, and biomechanical errors in nursing. Int Arch Occup Environ Health. 1998;71:336–342.
12. Application of OWAS Gangopadhyay S, Das B, Das T, Ghoshal G. An ergonomic study on posture-related discomfort among preadolescent agricultural workers of West Bengal, India. Int J Occup Saf Ergon. 2005;11:315–322.
13. Gomez MI, Hwang S, Stark AD, May JJ, Hallman EM, Pantea CI. An analysis of self-reported joint pain among New York farmers. J Agric Saf Health. 2003;9:143–157.

14. Hagberg M, Wegman DH. Prevalence rates and odds ratios of shoulder diseases in different occupational groups. Brit J Ind Med. 1987;44:602–610.
15. Hartman E, Oude Vrielink HH, Huirne RB, Metz JH. Risk factors for sick leavedue to musculoskeletal disorders among self-employed Dutch farmers: a case-control study. Am J Ind Med. 2006;49:204–214.
16. Hignett S. Postural analysis of nursing work. Appl Ergon. 1996;27:171–176.
17. Hildebrand VH. Back pain in the working population: prevalence rates in Dutch trades and professions. Ergonomics. 1995;38:1283–1298.
18. Holmberg S, Thelin A, Stiernstrőm EL, Svärdsudd K. The impact of physical work exposure on musculoscеletal symptoms among farmers and rural non-farmers. A population based study. Ann Agric Environ Med. 2003;10:179–184.
19. Holmberg S, Stiernstrőm EL, Thelin A, Svärdsuud K. Musculoskeletal disorders among farmers and non-farmers. Int J Occup Environ Health. 2002;8:339–345.
20. Holmberg S, Thelin A, Stiernström EL, Svärdsudd K. Low back pain comorbidity among male farmers and rural referents: a population-based study. Ann Agric Environ Med. 2005;12:261–268.
21. Hoogendoorn W, van Poppel M, Bongers PM, Koes BW, Bouter LM. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health. 1999;25:387–403.
22. Karhu O, Härkönen R, Sorvali P, Vepsäläinen P. Observing working postures in industry: Examples of OWAS application. Appl Ergon. 1981;12:13–17.
23. Karhu U, Kansi P, Kourinka I. Correcting working postures in industry. A practical method for analysis. Applied Ergonomics. 1986;8:199–201.
24. Karhu O, Kansi P, Kuorinka I. Correcting working postures in industry: A practical method for analysis. Appl Ergon. 1977;8:199–201.
25. Kivi P, Mattila M. Analysis and improvement of work postures in the building industry: application of the computerised OWAS method. Appl Ergon. 1991;22:43–48.
26. Leigh JP, Sheetz RM. Prevalence of back pain among fulltime United States workers. Br J Ind Med. 1989;46:1599–1607.
27. Maetzel A, Mäkelä M, Hawker G, Bombardier C. Osteoarthritis of the hip and knee and mechanical occupational exposure- a systematic overview of the evidence. J Rheumatol. 1997;24:1599–1607.
28. Nevala-Puranen N. Reduction of farmers' postural load during occupationally oriented medical rehabilitation. Appl Ergon. 1995;26:411–415.
29. Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. Am J Ind Med. 2008;51:443–451.
30. Perkio-Makela MM. Finnish farmers' self-reported morbidity, work ability, and functional capacity. Ann Agric Environ Med. 2000;7:11–16.
31. Pinzke S. Changes in working conditions and health among dairy farmers in southern Sweden. A 14-year follow-up. Ann Agric Environ Med. 2003;10:185–195.
32. Pinzke S, Stål M, Hannson GA. Physical workload on upper extremities in various operations during machine milking. Ann Agric Environ Med. 2001;8:63–70.
33. Rok S, Wytrążek M, Bilski B. Efficiacy of therapeutic exercises in low back pain surveyed in a group of nurses. Med Pr. 2005;56:235–239.
34. Rosecrance J, Rodgers G, Merlino L. Low back pain and musculoskeletal symptoms among Kansas farmers. Am J Ind Med. 2006;49:547–56.
35. Sandmark H, Hogstedt C, Vingård E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand J Work Environ Health. 2000;26:20–25.
36. Scott GB, Lambe NR. Working practices in a perchery system, using the OVAKO Working posture Analysing System (OWAS). Appl Ergon. 1996;27:281–284.
37. Stål M, Pinzke S, Hansson GA, Kolstrup C. Highly repetitive work operations in a modern milking system. A case study of wrist positions and movements in a rotary system. Ann Agric Environ Med. 2003;10:67–72.
38. Stål M, Hansson GA, Moritz U. Wrist positions and movements as possible risk factors during machine milking. Appl Ergon. 1999;30:527–533.
39. Stål M, Moritz U, Gusstafsson B, Johansson B. Milking is a high-risk job for young females. Scand J Rehab Med. 1996;28:95–104.
40. Stiernstrom EL, Holmberg S, Thelin A, Svardsudd K. Reported health status among farmers and nonfarmers in nine rural districts. J Occup Environ Med. 1998;40:917–924.
41. Thelin A. Hip joint arthrosis: An occupational disorder among farmers. Am J Ind Med. 1990;18:339–343.
42. Thelin A. Morbidity in Swedish farmers, 1978–1983, according to national hospital records. Soc Sci Med. 1991;32:305–309.
43. Thelin N, Holmberg S, Nettelbladt P, Thelin A. Mortality and morbidity among farmers, nonfarming rural men, and urban referents: a prospective population-based study. Int J Occup Environ Health. 2009;15:21–28.
44. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. Occup Med (Lond) 2002;52:441–450.
45. www.turwa1.me.tut.fi/owas
46. Vingård E, Alfredsson L, Goldie I, Hogstedt C. Occupation and osteoarthrosis of the hip and knee: a register-based cohort study. Int J Epidemiol. 1991;20:1025–1031.

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