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PRELIMINARY RECOGNITION OF WHOLE BODY VIBRATION RISK IN PRIVATE FARMERS' WORKING ENVIRONMENT

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Abstract: The objective of the study was the preliminary recognition of whole body mechanical vibration risk among farmers in the rural work environment. The study covered 15 farms using cultivated land of the size of over 10 ha, carrying out mixed production (plant-animal), equipped with agricultural tractors, and a basic set of tractor-mounted agricultural machinery, with a partial contribution of self-propelled agricultural machines. The scope of the study covered the measurements of effective vibration RMS acceleration (equivalent, maximum, minimum, peak) frequency corrected on the seats of agricultural vehicles in the three spatial directions of vibration (X, Y, Z). These measurements were realized while performing various field and transport work activities during the period of the whole year. A analysis of the peak, maximum and minimum vibration accelerations confirms that in the agricultural occupational environment there occurs a considerable variation of the vibration values registered. This is also evidenced by high values of the Crest Factor, sometimes exceeding a score of 10. Analysis of the registered equivalent values of vibration acceleration (frequency corrected) from the hygienic aspect showed that vibration occurring on the seats may create risk for farmers' health while performing such work activities as: tedding and raking of hay, fertilizers spreading, soil aggregation, grass mowing and cultivation. Analysis of the spatial distribution of the measured, frequency corrected vibration accelerations indicates that considerably the highest acceleration values occur in the vertical plane (direction – Z). Literature data clearly confirm an unfavourable effect of whole body vibration present in agricultural vehicles on discomfort and the occurrence of back pain in the operators, especially in the low back region (lumbar spine), as well as degenerative changes in the spine.

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Key words: whole body vibration, tractor operators, corrected vibration acceleration, field work activities, back pain, degenerative changes in the spine.

INTRODUCTION

Noise and vibration often occur together. They are analysed as technical conditions (noise and infrastructure vibration are inherent characteristics of transportation) and as occupational factors. We are interested in both of them as occupational hazards in agriculture. Previously we analysed exposure to noise among private farmers [16, 17]. Whole body mechanical vibration will be analysed in this paper. The basic sources of this vibration in agriculture are vehicles, primarily wheeled agricultural tractors of various types [18] with a wide range of power output, and self-propelled machinery – mainly grain combine harvesters, straw cutters, reaper mowers and sugar beet combine harvesters.

Few environmental studies conducted to-date confirm that the highest levels of vibration measured at the seats of agricultural tractors remain mainly within the range of low frequencies (1-10 Hz), equivalent to the resonance frequencies for various human body organs [6, 7, 18, 20]. Mechanical vibration with the above-mentioned characteristics may cause serious disorders in the functioning of these organs or systems, and in the case of high intensity of

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mechanical stimulus may lead to their impairment. This is evidenced by the dislocation of the tissues and organs with respect to one other, which causes the stretching or compression of the ligaments, connective tissue in the joints or intervertebral discs.

Literature data show that long-lasting effect of the whole body mechanical vibration may induce in the human body a number of non-specific changes of various characters within organs and systems: motor system, alimentary system, reproductive system in females, sense organs and peripheral circulatory system [10, 11, 12]. Increasingly more often, however, there appear reports concerning complaints in the region of the spine, reported by employees exposed to whole body vibration, including farmers [1, 2, 3, 5, 13, 14, 15]. Farmers most frequently complain of pain located in the lumbar region of the spine [4, 9, 21]. Changes in the spine confirmed by radiological examinations concern discopathy and degenerative deformities of the vertebral discs and joints, which may be primarily caused by the effect of mechanical vibration on the whole body. The occurrence of mechanical shocks in the farmers' work environment may result in a higher degree of lesions of the spine.

In order to preliminarily recognize risk due to whole body mechanical vibration among farmers in the rural occupational environment, studies were conducted within the statutory problem [19], which is the objective of the presented study.

MATERIAL AND METHODS

The study covered 15 farms selected in the area of 2 communes in the Lublin Region using arable land of the size of over 10 ha, executed in mixed production (plant-animal), equipped with agricultural tractors and a basic set of tractor-mounted agricultural machinery, with a partial contribution of self-propelled agricultural machines.

The scope of the study covered the measurements of effective vibration RMS acceleration (equivalent, maximum, minimum, peak) frequency corrected on seats of agricultural vehicles in the 3 spatial directions of vibration (X, Y, Z). The following scientific equipment which satisfied the research requirements was applied in the study: SVANTEK portable analyser of sound and vibration SVAN 912 AE, 4-channel measurement module SV 06A, and Emsonmat PD 3s triaxial seat sensor.

The measurements of mechanical vibration were conducted at the seats of 12 various types of high, medium and low power agricultural tractors; the majority of which were Polish made medium-power tractors, especially the C-360 type (the tractors most frequently used on private farms). The measurements were performed during various basic field and transport work activities throughout the whole year.

The evaluation of the degree of changeability of the accelerations measured were based on the registration, within the defined time intervals, of the following values: peak (Peak), minimum (Min), maximum (Max) and equivalent (Eq). The indicator of the changeability of the runs registered was also the so-called Crest Factor, defined as a ratio of peak value to the equivalent vibration acceleration value, in a defined vibration course, for an established time interval.

For the evaluation of the degree of risk caused by whole body mechanical vibration a basic vibration parameter was used, i.e. vibration acceleration (m/s^2) defined by an effective value (RMS) within the scope of Slow detector.

A basis for the hygienic analysis of the vibration courses registered were the obtained values of so-called frequency corrected vibration acceleration, with the use of correction filters referring to the 3 vibration directions (Z, X, and Y): W-Bz, W-Bx, and W-By.

RESULTS

Evaluation of the degree of changeability of vibration acceleration on the seats of agricultural vehicles covered 30 field and transport work activities performed by private farmers on the selected 15 farms during the whole year. The work activities were as follows: soil cultivation with the use of a cultivator, harrow or string shaft (5 work activities), fertilizer spreading with the use of fertilizer spreading distributor (3 activities), grain sowing with the use of a grain drill (2 activities), tedding, raking and pressing of hay with the use of a hay making machine and hay press with a high pressing degree (5 activities), soil aggregation with the use of a soil aggregator (3 activities), cutting and grinding of maize with the use of a maize straw cutter (3 activities), and single work activities (9 activities) associated with discing of soil (disc harrow), transport and manure spreading (manure spreader), deep ploughing (five furrow slice plough), cutting carrot tops (tops cutter), sugar beet digging (sugar beet combine harvester), straw pressing (press with high degree of pressing), driving along a field road with the pressing machine, potato digging (potato combine harvester 'Anna') and grass mowing (rotary mower).

The results of the measurements of mechanical vibration (Tab. 1) clearly show that considerably most often the highest values for vibration acceleration, irrespective of the work activities performed, occur in the vertical plane (vibration direction – Z); with the following exceptions: straw pressing, grinding of maize, driving along a field road – maximum acceleration in the horizontal plane (vibration direction – X and Y).

In the case of the horizontal plane, the values of the vibration registered were more varied, sometimes with a higher emission of vibration in the longitudinal direction (X) or transverse direction (Y), or adopted similar values in both directions.

The analysis of the minimum (Min), maximum (Max), and peak (Peak) values of vibration acceleration obtained shows a high distribution of the data registered. For the

Table 1. Results of frequency corrected vibration accelerations registered on tractor seats while performing various field work activities.

No.	Type of work activity performed (machine)	Vibration direction	Measured vibration values (m/s^2)				
			E_q	Min	Max	Peak	CrF
1	Cultivation (cultivator, harrow)	Z	0.460-0.989	0.001-0.070	2.113-3.311	6.918-10.12	7.00-22.10
		X	0.324-0.569	0.001-0.018	1.318-2.692	3.055-5.754	7.50-12.40
		Y	0.275-0.569	0.002-0.071	1.109-2.371	2.483-4.519	6.76-14.50
2	Fertilizer spreading (fertilizer spreading distributor)	Z	0.680-1.350	0.001-0.100	2.723-8.610	9.886-22.13	7.59-32.70
		X	0.501-0.841	0.001-0.063	1.274-2.239	2.851-4.732	2.851-4.732
		Y	0.537-0.870	0.001-0.047	1.288-14.13	3.055-29.51	5.31-33.90
3	Sowing grain (grain drill)	Z	0.363-0.457	0.001-0.071	1.334-2.089	5.188-6.683	14.30-14.60
		X	0.214-0.302	0.001-0.029	1.349-1.514	3.020	10.00-14.10
		Y	0.202-0.266	0.001-0.060	0.933-1.059	1.995-2.065	7.76-9.89
4	Tedding, raking and pressing hay (hay making machine, hay press)	Z	0.462-1.780	0.003-0.031	1.950-3.630	4.315-12.59	7.08 –21.40
		X	0.380-0.804	0.001-0.021	1.161-1.884	2.754-3.981	4.95 –10.50
		Y	0.309-0.912	0.003-0.040	0.759-2.985	1.445-5.309	4.68 –15.80
5	Soil aggregation (soil aggregator)	Z	0.054-0.912	0.001-0.071	0.188-2.985	0.767-9.550	10.10-14.10
		X	0.043-0.479	0.001-0.021	0.224-1.603	0.462-2.818	5.89-10.80
		Y	0.041-0.631	0.001-0.022	0.145-1.718	0.316-3.548	5.62-7.57
6	Cutting and grinding maize (maize straw cutter)	Z	0.041-0.468	0.001-0.040	0.479-2.723	3.055-10.00	16.20-74.20
		X	0.209-0.243	0.001-0.016	0.804-0.891	1.820-2.661	8.13-12.70
		Y	0.245-0.292	0.001-0.015	0.966-1.288	1.660-2.630	6.53-10.70
7	Discing of soil (disc harrow)	Z	1.120	0.010	4.070	13.34	11.90
		X	0.582	0.001	1.841	4.677	8.04
		Y	0.832	0.002	2.630	6.683	8.04
8	Transport and manure spreading (manure spreader)	Z	0.790	0.020	3.550	14.13	17.80
		X	0.442	0.014	1.413	2.818	6.38
		Y	0.490	0.011	1.660	3.020	6.17
9	Deep ploughing (five-furrow plough)	Z	0.813	0.005	2.630	6.761	8.32
		X	0.398	0.003	1.799	4.266	10.70
		Y	0.380	0.005	1.303	3.236	8.51
10	Cutting carrot tops (tops cutter)	Z	0.580	0.030	7.080	26.92	46.80
		X	0.275	0.027	0.933	2.483	9.02
		Y	0.288	0.072	1.641	3.758	13.00
11	Sugar beet digging (sugar beet combine harvester)	Z	0.447	0.003	1.429	5.495	12.30
		X	0.257	0.001	1.189	2.483	9.66
		Y	0.260	0.004	0.977	2.065	7.94
12	Straw pressing (press with high degree of pressing)	Z	0.004	0.002	0.008	0.029	6.53
		X	0.531	0.001	0.966	2.089	3.94
		Y	0.363	0.001	1.189	2.570	7.08
13	Driving along a field road with pressing machine	Z	0.005	0.003	0.011	0.042	9.23
		X	0.347	0.001	1.059	2.951	8.51
		Y	0.363	0.001	1.349	3.162	8.71
14	Potato digging (potato combine harvester)	Z	0.543	0.001	1.496	3.162	5.82
		X	0.295	0.001	1.514	3.890	13.20
		Y	0.251	0.001	2.138	5.623	22.40
15	Grass mowing (rotary mower)	Z	1.047	0.046	2.951	8.710	8.32
		X	0.447	0.011	2.018	4.416	9.89
		Y	0.335	0.011	1.445	3.673	11.00

E_q – equivalent values; Min – minimum values; Max – maximum values; Peak – peak values; CrF – crest factor.

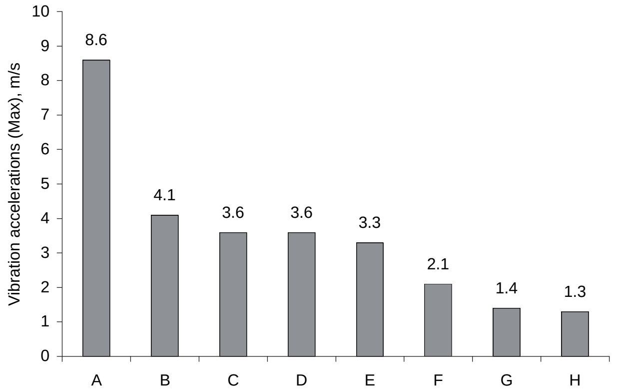

Figure 1. Maximum acceleration values on tractor seats according to the type of work activities (Z – direction) registered at: A – fertilizers spreading; B – aggregation and discing of soil; C – transport and manure spreading; D – tedding and raking of hay; E – cultivation; F – potato digging; G – sugar beet digging; H – driving along a field road.

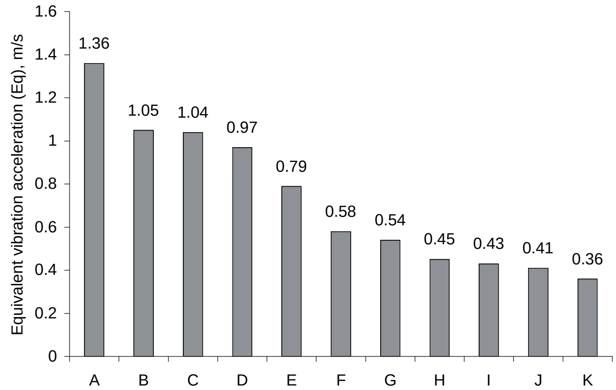

Figure 2. Equivalent frequency corrected vibration acceleration values for various field and transport work activities (mean values; direction – Z) registered at: A – tedding and raking of hay; B – grass mowing; C – fertilizer spreading; D – soil aggregation; E – cultivation; F – cutting carrot tops; G – potato digging; H – sugar beet digging; I – cutting and grinding maize; J – sowing grain; K – driving along a field road.

maximum vibration acceleration values the highest data was noted while performing such work activities as: spreading of fertilizers (up to 8.6 m/s^2), aggregation and discing of soil (up to 4.1 m/s^2), transport and spreading of manure (3.6 m/s^2), tedding and raking of hay (3.6 m/s^2) and cultivation (up to 3.3 m/s^2), whereas the lowest values were observed while driving along a field road (1.3 m/s^2), sugar beet digging (1.4 m/s^2) and potato digging (2.1 m/s^2). Peak values were characterized by a similar data distribution (3.1-5.5 m/s^2 during driving along a field road, sugar beet digging and potato digging, and 13.3-22.1 m/s^2 during aggregation and spreading of fertilizers). Figure 1 presents the mean values of maximum vibration acceleration (direction Z) on tractor seats according to the type of work activities performed.

The high Crest Factor values obtained also evidence great changeability of data, sometimes reaching values exceeding 10 (maximum values obtained: 17.8 while manure spreading, 21.4 during hay pressing, 22.1 during cultivation and 11.0-33.9 while spreading fertilizers).

A basis for the hygienic analysis of the registered vibration courses are the values of frequency corrected vibration accelerations, referring to the 3 directions of vibration (Z, X and Y). The equivalent values of vibration acceleration obtained (Eq) indicate that considerably the highest values of frequency corrected acceleration values occur while performing the following work activities: tedding and raking of hay (0.94-1.78 m/s^2), spreading of fertilizers (0.87-1.35 m/s^2), aggregation of soil (0.87-1.12 m/s^2), grass mowing (1.05 m/s^2), and cultivation (0.46-0.99 m/s^2).

The lowest vibration values, however, were noted while driving at low speed along a field road (0.36 m/s^2), sugar beet digging (0.45 m/s^2), sowing of grain (0.36-0.46 m/s^2), cutting and grinding of maize (0.25-0.47 m/s^2), potato digging (0.54 m/s^2), and cutting carrot tops (0.58 m/s^2).

It is noteworthy that slightly lower values of vibration acceleration are noted on the seats of Czech made tractors, compared to other producers, this especially concerns the Zetor 7211 at work with cultivation aggregate and Zetor 5211 during the grinding of maize.

While analysing the type of field work activities performed and tractor type it may be presumed that the highest vibration accelerations occur on tractor seats while soil harrowing with the use of tractor type C-360, straw pressing with a C-360 tractor, grass mowing with a U-4512, and during harrowing with a C-330; while the lowest values are observed during potato digging with a Zetor 5211 and maize grinding with a Zetor 5211.

Figure 2 presents the mean frequency corrected equivalent vibration acceleration values noted for various field and transport work activities (direction – Z).

DISCUSSION

The analysis of the peak, maximum, and minimum vibration acceleration values confirms that in the agricultural work environment there occurs a considerable variation in the vibration values registered, which is also evidenced by high peak value coefficients, sometimes exceeding 10. The occurrence of such a great distribution of vibration acceleration may be explained by mechanical shocks induced on tractor seats. These are phenomena especially dangerous for the human organism, leading to considerable damage of the spine, especially in the lumbar region.

The presented analysis of equivalent values of vibration acceleration (frequency corrected) from the hygienic aspect confirmed that vibration courses occurring on tractor seats while performing such work activities as: hay tedding and raking, fertilizers spreading, soil aggregation, grass mowing and cultivation may create an especially high risk for farmers' health. These work activities are performed with elevated tractor operation velocities, most often along hard and unequal surfaces. Considerably lower vibration acceleration values, however, were noted while driving at low speed along a field road, sugar beet and potato digging, cutting and grinding of maize. These work activities are performed with low operation velocity (tractor + agricultural machine) over a soft surface.

Analysis of the distribution of the measured, frequency corrected vibration acceleration shows that the highest acceleration values occur in the vertical plane (direction – Z), while the direction – X (longitudinal, parallel to the direction of tractor's movement) is more dominant in the horizontal plane.

Literature data clearly confirm an unfavourable effect of whole body vibration present in agricultural machines on discomfort and the occurrence of back pain in operators, especially concerning low back (lumbar spine). Kohl [13] conducted survey studies among 582 farmers, concerning the effect of low frequency mechanical vibration induced by tractors on the human organism. The results of this survey showed that 61% of farmers in the study had back pain, while 61% of them also reported complaints on the part of the alimentary system. A significant correlation was observed between these disorders and tractor operating.

Subsequently, Hildebrandt [9] confirmed a high risk of the occurrence of symptoms concerning the musculoskeletal system in farmers. These symptoms were observed in 49% of agricultural workers, among 2,728 people employed in agriculture in 15 various occupational branches.

Also, Barbieri *et al.* [1], Bovenzi & Betta [4], Boshuizen *et al.* [3], Palmer *et al.* [15] and Manninen *et al.* [14] confirmed the considerably more frequent occurrence of back pain among tractor operators, compared to the control group not exposed to whole body vibration. The occurrence of this pain increased with the vibration dose absorbed.

The review of epidemiological studies conducted by Bovenzi & Hulshof [5], which was an attempt to determine the relationship between exposure to whole body vibration and back pain, and covered the reports concerning the period 1986-1997, showed that this vibration exerts an unfavourable effect on the health of tractor operators, especially on the spinal system. Occupational exposure to whole body vibration is accompanied, in the authors' opinion, by an increase in the occurrence of back pain (in the lower section of the spine), ischiadic nerve pain (ischias), and degenerative changes in the spine, including the deformation of the lumbar discs. Degenerative changes in the lumbar spine were also observed by Stawczyk [21] among tractor operators, and concerned 45.8% of the people in the study.

It should also be emphasized that manually operated (performing mobile action while in a standing position) single-axle tractors are sometimes used in agriculture. Vibration occurring on the handles of these machines cause vascular, neurological and musculoskeletal changes, resulting in vibration-induced white finger syndrome [8].

The results of the studies obtained provide a preliminary recognition of the problem of farmers' health risk caused by whole body mechanical vibration. In order to recognize this risk more comprehensively, studies of this type should be continued, considering the evaluation of the dose of the vibration absorbed by the operators of tractors and agricultural machines during the period of the whole year.

CONCLUSIONS

1. The conducted studies of mechanical vibration exerting a general effect on the whole body occurring on the seats of agricultural tractors showed that the highest acceleration values are emitted during agricultural work activities performed with an elevated operation velocity, along a hard surface and unequal surfaces.

2. The vibration analysed is characterized by a high variation (due to the contribution of mechanical shocks), with maximum values noted within the range of low frequencies.

3. The spatial analysis of vibration indicated that considerably the highest values of corrected vibration acceleration occur in the vertical plane (direction – Z).

4. Considering the aspect of the occurrence of high health risk caused by the whole body mechanical vibration, the studies undertaken in the agricultural work environment should be continued, taking into account the exposure to vibration during the period of the whole year (vibration doses).

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