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ASSESSMENT OF ANNUAL EXPOSURE OF PRIVATE FARMERS TO WHOLE BODY MECHANICAL VIBRATION ON SELECTED FAMILY FARMS OF PLANT PRODUCTION PROFILE

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Abstract: The objective of the study was evaluation of an annual exposure of private farmers to whole body mechanical vibration on selected family farms of plant production profile. The study covered 15 family farms, using arable land of the size of 10–50 ha (22.3 ha on average), engaged mainly in plant production, and equipped with tractors, tractor-mounted agricultural machinery, with a partial contribution of self-propelled machines. The scope of the study covered the carrying out of time schedules of agricultural activities, and measurements of effective values (RMS) for vibration acceleration (equivalent), frequency corrected, on the seats of farm vehicles in 3 spatial directions of vibration (X, Y, Z). The measurements were made while performing various basic field and transport work activities during the period of the whole year. The study showed (plant production) that the degree of whole body mechanical vibration load among farmers during the whole year depends on the vibration level and duration of exposure to this factor. The highest values of the total vibration dose (d) occur both during summer-autumn months (August, September, October and November), and in spring (April, May). The mean equivalent of daily vibration acceleration shows the highest values during 4 months of the year: April and May (0.52 m/s^2), and in August and September (0.56–0.57 m/s^2); the average value of this parameter, for the whole year, reaches the level of 0.45 m/s^2. Considering the fact of the occurrence of mechanical shocks in agricultural vehicles (high maximum accelerations values registered: 0.81–1.01 m/s^2; standard exceeding), and exceeding of the *daily exposure action value*, proper steps should be undertaken with respect to the protection of private farmers against risk resulting from exposure to mechanical vibration while performing work activities.

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INTRODUCTION

Whole body vibration (WBV), apart from noise [24, 25], is among the most common occupational hazards occurring in the work environment of farmers. The vibration occurs on the seats of agricultural vehicles in motion, and during the performance of specified field and transportation work tasks [8, 9, 23]. Operators of single-axle agricultural tractors are exposed to mechanical vibration transmitted from the grip of the machine to the operator's hands [10].

Preliminary studies of mechanical vibration [26] emitted by agricultural vehicles indicated that vibration patterns which occur on seats during the performance of such work tasks as: hay tedding and raking, sowing fertilizers, aggregation of soil, mowing of grass and cultivation, may create an especial risk for farmers' health. These are work tasks

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performed with an elevated work speed of tractors, most often over a hardened and uneven surface.

A long-time effect of the whole body vibration may induce in a human body a number of non-specific changes of various character within organs and systems [12, 13, 14], such as, motor organs, alimentary system, female reproductive system, organs of senses, and the cardiovascular system. Increasingly more often there appear reports concerning disorders in the region of the spine, reported by workers exposed to whole body vibration, including farmers [1, 2, 3, 5, 6, 15, 16, 17, 31, 35]. Farmers most often complain of pain in the lumbar region [4, 11, 16, 19, 30, 32, 33]. Changes observed in the spine (radiologic examination) concern discopathy and degenerative deformation of the vertebrae and joints, the primary cause of which may be the effect of whole body mechanical vibration. In this occupational group, mechanical shocks occurring in the work environment may be decisive concerning a higher degree of spine lesions [26, 28, 34].

Considering the large number of field and transport work activities performed in various meteorological and soil conditions, as well as the changeable time of daily exposure to vibration, the only adequate method for evaluation of the degree of whole body mechanical vibration risk among farmers is the performance of examinations during the whole calendar year. Evaluation of farmers' annual exposure to whole body vibration according to the type of agricultural production (plant, animal, mixed) is a relatively poorly recognized problem [32].

Investigations have been undertaken within the grant project in order to recognize and evaluate the annual exposure of private farmers to whole body mechanical vibration on selected family farms of plant production profile [27], this problem being the objective of the presented study.

MATERIAL AND METHODS

The study covered 15 family farms located in the area of 4 communes in the Lublin Region, using arable land of the size 10–50 ha (22.3 ha on average), engaged mainly in plant production. These farms were equipped with tractors, tractor-mounted agricultural machinery, with a partial contribution of self-propelled machines (cereal combine harvesters).

Among 35 tractors used on selected farms the majority were medium-power tractors (13 tractors; including C-360: 8 tractors, and MF-255: 5 tractors), and high-power tractors (9 tractors, including C-385: 3 tractors, of the U-1002-1014 series: 3 tractors, and MTZ-82: 3 tractors). Low-power tractor were used to a smaller extent (7 tractors – primarily C-330), and Czech produced tractors (6 Zetor tractors, respectively).

Selected farms specialized mainly in the production of cereals, and partially also in the production of root plants (sugar beets, potatoes), vegetables and apples, and small amounts of animal fodder (green forage, hay).

The scope of the study covered the following:

- carrying out time schedules of agricultural activities performed by farmers on their own farms, during which there occurred exposure to vibration (measurements were performed by farmers under the supervision and control of the research team from the Institute);
- measurement of the effective values (RMS) for vibration acceleration (equivalent), frequency corrected, on the seats of farm vehicles in 3 spatial directions of vibration (X, Y, Z).

Both time-schedule and vibration measurements were carried out while performing by farmers (every day) basic field and transport activities, during the whole calendar year.

In the studies, the SVANTEK scientific equipment was used, which satisfied the research requirements, including: portable analyser of sound and vibration SVAN 912 AE, 4-channel measurement module SV 06A, and Emsonmat PD 3s triaxial seat sensor. The devices were equipped with correction filters referring to the 3 vibration directions and marked by the symbols: W_k (whole body vibration, vertical, Z axis), and W_d (whole body vibration horizontal, X or Y axes) which allowed the obtaining of frequency-corrected vibration acceleration.

In order to evaluate of the level of farmers' exposure to whole body vibration, a vibration parameter was used – the vibration dose (d) [18], calculated by means of the following formula:

$$d = \sum_{i=1}^{n} a_{w,i}^{2} \cdot t_i$$

where:

d – vibration dose;

$a_{w,i}$ – frequency corrected value of vibration acceleration within the time interval i (m.s^{-2});

t_i – vibration time within the time interval i (hour).

The definition of vibration dose contains 2 physical values, i.e. vibration intensity expressed by frequency weighted acceleration value a_w, and vibration duration within the specified time intervals i. The vibration unit is $m^2 \cdot s^{-4} \cdot h$.

Based on precise time-schedules performed and the results of measurements of vibration acceleration, data was obtained which is evidence of the level of farmers' exposure to whole body vibration, and the duration of exposure to vibration in individual months of the year. The following values were determined for the calculated vibration dose (d): total monthly vibration dose, and mean equivalent daily vibration dose (referring to the legal work days monthly). The mean equivalent daily vibration dose (for an individual month) is the value obtained from the ratio of total monthly vibration dose and number of legally established workdays in a given month.

Statistical analysis was performed by means of SPSS/PC computer software [29]. The following statistical parameters were analysed: normality of distribution (skewness, kurtosis, Kolmogorov-Smirnov test), and the mean values (arithmetic), the degree of data dispersion (range, standard deviation, confidence intervals). In order to determine the degree of variation of the results of studies obtained, the analysis of variance was performed (single-factor ANOVA) by F test, calculated as a ratio between extra-group to intra-group variation (independent samples, of normal distribution, possessing homogenous variances), expressed as the mean sum of squares. Leven test was applied to investigate the homogeneity of variance. For the assessment of the differences occurring between the mean values obtained, referring to individual months of the year, Duncan's multiple range test was used. For all the tests applied, the statistical significance level was set at $p \geq 0.05$.

RESULTS

The basic statistical data concerning the total monthly dose of mechanical vibration in individual months of the calendar year analysed were compiled in Table 1. The data presented show the occurrence of great changeability of the results of studies and their high variation. An especially high data distribution was obtained in January, February, June, November and December, which is indicated by high values of standard deviations (with relation to mean values), a wide scope of the values measured (range), and high values of kurtosis coefficient (k) and skewness coefficient (α). Despite such dispersion, the data distribution in these months still remain within the range of normal distribution (Kolmogorov-Smirnov test: p = 0.20–0.35). A better data distribution, similar to the normal distribution (p = 0.51–0.67), was noted in March, May and October (lower values of the statistical parameters analysed above). Considerably the best data distribution, closest to the normal distribution (p = 0.82–0.97), was observed in April, July, August and September (the smallest standard deviations, low values of kurtosis and skewness coefficients, and smallest range of the values measured – with relation to the mean values).

In order to assess within what interval, at an established level of confidence, the actual mean monthly vibration dose may be expected, confidence intervals were calculated (for the adopted level of confidence equal 95% and two-sided Student's test, 2.5% of confidence level at each side). Confidence intervals within which the mean values are comprised, cover a relatively varied range, according to an individual month. The smallest width of the confidence interval was noted in 5 months: April, July, August, September and October (the ratio of the upper confidence limits to mean values assumes: 1.19–1.25, which is equivalent in a logarithmic scale to the value of 0.8–1.0 dB). Changing a scale from linear to logarithmic consists in the conversion of data according to the formula: $L_{dB} = 10 \log CI_{max}/Mean$; where CI_{max} – is the value of upper confidence limit; Mean – mean arithmetic value.

During the remaining months (January–March, May–June, November–December), the width of the confidence interval was larger, while the upper confidence limits, with relation to mean values, assumed data within the range from $[1.30–1.57] \cdot x_{mean}$; (1.1–2.0 dB) for June, May, March, November, January and February – to $1.65 \cdot x_{mean}$; (2.2 dB) in March.

Analysis of variance (ANOVA) performed for the total monthly mechanical vibration dose showed that variances determined in individual months of the year significantly differed statistically (F test = 10.224; p = 0.0001). Also, the Leven test for homogeneity of variance indicated that the mean values obtained were characterised by a varied homogeneity (S = 2.549; p = 0.005). The analysis of the significance of the differences between pairs of individual months of the year performed by means of Duncan's test confirmed that there was no variation between mean total doses in December, January and February (p = 0.771); March, June, July and November (p = 0.52); April, May, June, July, October and November (p = 0.093); April, May,

Table 1. Statistical values of total monthly dose of mechanical vibration (d) $[m^2 \cdot s^{-4} \cdot h]$.

Months	Mean ± SD	CI	α	k	Range	p
January	9.58 ± 9.08	4.10–15.07	0.88	−1.13	1.24–24.34	0.20
February	11.75 ± 8.68	6.51–17.00	1.76	3.05	3.85–34.39	0.29
March	26.55 ± 15.85	17.39–35.70	1.33	2.20	4.72–66.90	0.55
April	43.82 ± 16.95	34.43–53.21	−0.38	−1.03	12.51–67.36	0.97
May	45.18 ± 27.14	30.15–60.21	1.08	0.98	13.26–109.69	0.51
June	36.68 ± 19.85	25.69–47.67	1.37	2.42	9.96–87.59	0.25
July	31.54 ± 13.08	24.30–38.78	0.89	1.33	9.78–62.44	0.92
August	57.47 ± 19.95	46.42–68.52	0.49	−1.07	32.14–95.05	0.82
September	49.79 ± 21.92	37.65–61.93	0.58	−0.55	19.15–90.72	0.96
October	43.89 ± 19.84	32.90–54.87	0.40	−1.52	19.36–73.32	0.67
November	41.57 ± 27.72	25.57–57.58	1.40	1.63	8.80–106.85	0.35
December	9.54 ± 9.76	3.34–15.74	2.33	5.85	2.20–36.80	0.24
For whole year	33.95 ± 16.34	23.57–44.33	−0.49	−1.02	9.54–57.47	0.83

Mean – mean arithmetic value; SD – standard deviation; CI – confidence interval; α – skewness coefficient; k – kurtosis; Range – (min–max) range; p – probability normal distribution.

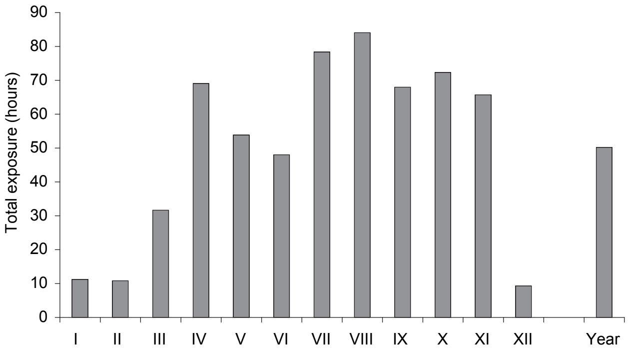

Figure 1. Mean values of total exposure (hours) in individual months.

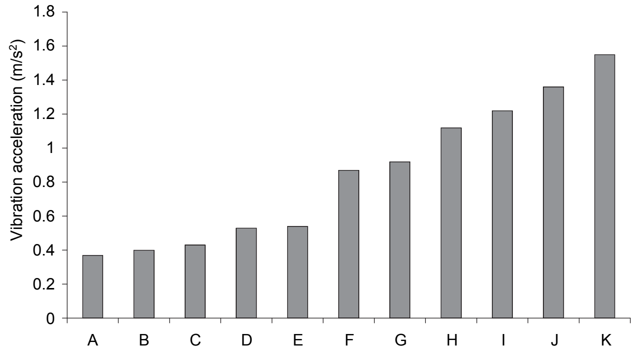

Figure 2. Equivalent values of vibration acceleration for different work activities. (A – cutting and grinding of maize; B – combine harvesting of cereal crops; C – beetroot digging; D – working with tractor front loader; E – potato digging; F – spreading of fertilizers; G – grass mowing; H – disc harrowing; I – transportation of manure (field road); J – hay tedding and raking; K – transport 2 trailers (asphalt road).)

June, September, October and November ($p = 0.108$); and April, May, August, September and October ($p = 0.087$).

Mean arithmetic values were selected for the analysis, and hygienic evaluation of average doses of mechanical vibration to which private farmers' were exposed, as the most adequate from the aspect of mechanical energy. The highest values of the mean (arithmetic) total vibration dose were observed during the following months: August (57.47 $m^2 \cdot s^{-4} \cdot h$), September (49.79), May (45.18), October (43.89), April (43.82), and November (41.57); whereas the lowest values were noted in December (9.54), January (9.58), and February (11.75).

High values of total vibration doses in summer and autumn (August, September, October, November) should be associated with the great intensification of work activities connected with soil cultivation and harvesting of root plants (mean values of the total time of exposure to vibration in these months were: from 66 hours in November to 84 hours in August – Fig. 1), and were characterised by the emission of vibration of high accelerations (this especially refers to transportation activities performed most often in these months – Fig. 2), a large number of workdays in conditions of exposure to vibration in these months (15–19 days on average – Fig. 3), as well as frequently prolonged duration of exposure on those workdays (4.7 hours daily on average; maximum up to 9.6 hours – Fig. 4; in single cases 15–17 hours).

High values of vibration doses in April and May are caused by both the prolonged time of exposure to vibration (mean total time: 54–69 hours), large number of workdays (17–18 on average), prolonged duration of exposure (4 hours daily on average; maximum 8.4 hours; in single cases 12–14 hours), and the performance of work activities characterised by the emission of high acceleration vibration in these months (transport, tedding and raking hay, disc harrowing, sowing of fertilizers, spraying) (Fig. 2).

In the case of the mean value referring to the whole calendar year (Tab. 1 – for the whole year), the mean monthly vibration dose was 33.95 ± 16.34 $m^2 \cdot s^{-4} \cdot h$, with the distribution of data equivalent to the normal distribution (Kolmogorov-Smirnov test; $p = 0.83$).

Table 2. Statistical values of mean equivalent daily dose of mechanical vibration (d) [$m^2 \cdot s^{-4} \cdot h$].

Months	Mean ± SD	CI	α	k	Range	p
January	0.44 ± 0.41	0.19–0.69	0.88	−1.11	0.06–1.11	0.20
February	0.59 ± 0.43	0.33–0.85	1.76	3.04	0.19–1.72	0.29
March	1.21 ± 0.72	0.80–1.62	1.32	2.18	0.21–3.04	0.55
April	2.19 ± 0.85	1.72–2.66	−0.38	−1.04	0.63–3.37	0.97
May	2.15 ± 1.29	1.44–2.87	1.07	0.98	0.63–5.22	0.51
June	1.83 ± 0.99	1.28–2.38	1.37	2.42	0.50–4.38	0.24
July	1.43 ± 0.60	1.10–1.76	0.88	1.34	0.44–2.84	0.93
August	2.61 ± 0.91	2.11–3.11	0.49	−1.07	1.46–4.32	0.81
September	2.49 ± 1.10	1.88–3.10	0.59	−0.54	0.96–4.54	0.96
October	1.91 ± 0.86	1.43–2.39	0.40	−1.52	0.84–3.19	0.67
November	1.98 ± 1.32	1.22–2.74	1.41	1.64	0.42–5.09	0.35
December	0.50 ± 0.51	0.17–0.83	2.33	5.86	0.12–1.94	0.24
For whole year	1.61 ± 0.77	1.12–2.10	−0.48	−1.19	0.44–2.61	0.75

Mean – mean arithmetic value; SD – standard deviation; CI – confidence interval; α – skewness coefficient; k – kurtosis; Range – (min–max) range; p – probability normal distribution.

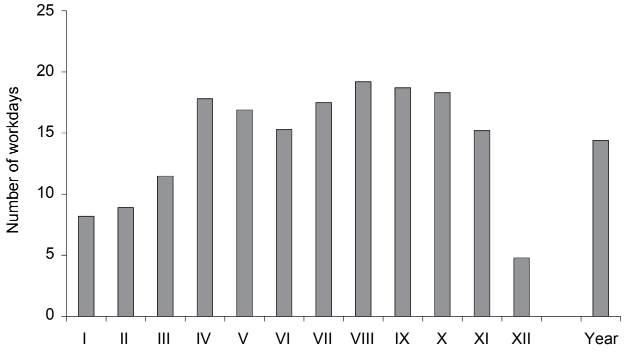

Figure 3. Mean number of workdays during a month in conditions of exposure to vibration.

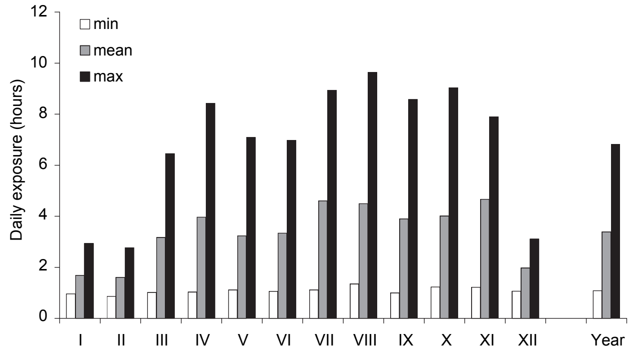

Figure 4. Daily exposure (hours) to vibration in individual months.

A more objective indicator of exposure, equivalent to the actual exposure to mechanical vibration, is the value of the mean equivalent daily vibration dose, referred to the legally established workdays in each month (40-work hours week; holidays and Saturdays free of work). As a result of the calculations performed, statistical data was obtained concerning this parameter (Tab. 2). The variation of the mean equivalent daily vibration dose is considerably smaller, compared to the total monthly vibration dose discussed (for the arithmetic mean it remains within the range 0.44–2.61 $m^2 \cdot s^{-4} \cdot h$). The greatest data dispersion was noted, as previously, in 5 months of the year, i.e. in January, February, June, November and December, which is evidenced by high values of standard deviations (compared to the mean values), a wide range of the mean values obtained (range), and high values of kurtosis (k) and skewness (α) coefficients. Despite such a dispersion, the distribution of data in these months still remain within the range of normal distribution (Kolmogorov-Smirnov test: p = 0.20–0.35). A slightly better data distribution, similar to normal distribution (p = 0.51–0.67), was observed in March, May and October (lower values of the statistical parameters analysed above). Considerably the best data distribution, and the closest to the normal distribution (p = 0.81–0.97), was noted in April, July, August and September (the lowest standard deviation, low kurtosis and skewness coefficients, and the smallest range of the values measured – with relation to the mean values).

Calculated values of the confidence interval for this vibration parameter maintain the distribution similar to monthly exposure. The narrowest confidence interval was obtained in April, July, August, September and October ([1.19–1.25]$\cdot x_{mean}$; 0.8–1.0 dB); this interval being wider during the remaining months of the year, adopting data within the range from [1.30–1.57]$\cdot x_{mean}$; (1.1–2.0 dB) in June, May, November, January and February to 1.65$\cdot x_{mean}$; (2.2 dB) in March.

Analysis of variances shows that variances specified in individual months of the year differ significantly statistically (F test = 10.055; p = 0.0001). Also, the Leven test for homogeneity of variance indicates that the mean values obtained are characterised by varied homogeneity (S = 2.474; p = 0.007). Studies of the significance of differences between the pairs of individual months performed by Duncan's test showed that there was no variation between mean daily doses with respect to the following months: December, January and February (p = 0.673); February and March (p = 0.068); March, June, July and October (p = 0.057); May, June, July, October and November (p = 0.058); April, May, August, September, October and November (p = 0.068).

Analysis of the data obtained shows that the highest mean value (arithmetic mean) of equivalent daily vibration dose were noted in the 2 summer–autumn months: August and September (2.49–2.61 $m^2 \cdot s^{-4} \cdot h$), and 2 months in spring: April and May (2.15–2.19 $m^2 \cdot s^{-4} \cdot h$).

The highest values of vibration doses in August and September are due to the high intensification of the transport activities performed, which are characterised by the emission of high acceleration vibration, the prolonged duration of daily exposure to vibration, and a considerable number of workdays in these months.

In April and May, transport activities of considerable intensity are performed, as well as hay tedding and raking, spraying, and work associated with soil management (cultivation, disc harrowing); these are tasks performed with high vibration levels. In these months, there occurs long-term exposure to mechanical vibration (long time of monthly exposure, prolonged duration of daily exposure, large number of workdays a month).

In order to evaluate the degree of farmers' risk caused by mechanical vibration, the obtained values of the equivalent daily vibration dose in individual months of the year were recalculated into vibration acceleration values – energy equivalent and frequency weighted, for 8-hour daily exposure. Table 3 presents the data obtained in this way. The mean values of vibration acceleration, according to individual months, remained within the range 0.23–0.57 m/s^2; with the highest values observed in April and May (0.52 m/s^2), and in August and September (0.56–0.57). The lowest values concerned January, February and December (0.23–0.27). Compared to the standard values (standard: A (8) = 0.8 m/s^2) [21], the values of mean equivalent vibration acceleration noted remain below allowable levels for all months of the year; this also concerns acceleration

Table 3. Statistical values of energy equivalent for an 8-hours daily exposure, frequency of weighted vibration acceleration [m/s²].*

Months	Mean ± SD	CI	Range	Maximum values	
				means	max instantaneous
January	0.23 ± 0.23	0.15–0.29	0.09–0.37	0.56	0.74
February	0.27 ± 0.23	0.20–0.33	0.15–0.46	0.62	0.83
March	0.40 ± 0.30	0.32–0.45	0.16–0.62	0.87	1.12
April	0.52 ± 0.33	0.46–0.58	0.28–0.65	0.91	1.29
May	0.52 ± 0.40	0.42–0.60	0.28–0.81	0.87	1.27
June	0.48 ± 0.35	0.40–0.55	0.25–0.74	0.94	1.36
July	0.42 ± 0.27	0.37–0.47	0.24–0.60	0.81	1.13
August	0.57 ± 0.34	0.51–0.62	0.43–0.74	1.01	1.34
September	0.56 ± 0.37	0.49–0.62	0.35–0.75	0.84	1.11
October	0.49 ± 0.33	0.42–0.55	0.32–0.63	0.84	1.11
November	0.50 ± 0.41	0.39–0.59	0.23–0.80	0.86	1.17
December	0.25 ± 0.25	0.15–0.32	0.12–0.49	0.63	0.98
For whole year	0.45 ± 0.31	0.37–0.51	0.24–0.57	0.81	1.12

Mean – mean arithmetic value; SD – standard deviation; CI – confidence interval; Range – (min–max) range.
*Converted from the value of equivalent daily vibration dose given in Table 2.

values within the confidence interval (CI). Also, the average value for the mean equivalent exposure to vibration (0.45 m/s²) calculated for the whole year did not exceed allowable values. The upper limits of vibration acceleration within the range for certain months were on the level of the standard (May: 0.81 m/s²; November: 0.80).

However, due to the high contribution of mechanical vibration shocks in the patterns registered [26, 28, 34], which created a great risk for the spine of operators of agricultural vehicles, in the hygienic evaluation of the degree of vibration risk momentary maximum vibration acceleration values cannot be omitted (induced by shocks), which obtain mean values within the range 0.56–1.01 m/s². For the majority of months, apart from January, February and December, these values exceed those allowable, reaching 0.81–1.01 m/s², especially in April (0.91 m/s²), June (0.94 m/s²), and August (1.01). In addition, the occurrence of single, highest vibration accelerations was observed of the value: 1.34–1.36 m/s² in June and August, and 1.27–1.29 m/s² in April and May.

The latest Polish legal regulations [20] concerning work safety and occupational hygiene while performing work activities associated with exposure to mechanical vibration, which are a basis for the EC Directive 2002/44 [7], define the *action value for daily exposure* to the whole body vibration at the level: $A(8)_w = 0.5$ m/s², the exceeding of which obliges the employers to undertake specified preventive actions.

In the light of the measurement data obtained, it should be stated that the mean vibration acceleration values exceeded the *daily exposure action value* during 4 months, i.e. April, May, August and September. Maximum values of vibration acceleration exceeded the *action value* in all months of the year.

DISCUSSION

The studies of an annual exposure of private farmers specialising in plant production to whole body mechanical vibration showed the occurrence of great complexity and changeability of the results within a time interval, which covered the whole calendar year. This is associated primarily with the type of agricultural and transport work activities performed within proper time intervals.

The degree of loading private farmers with mechanical vibration is conditioned, on the one hand, by the level of vibration transmitted from the seat of a vehicles to the whole body of an operator, and on the other hand, the duration of exposure to this factor within a proper time interval.

The results of the study show that the highest values of the total vibration dose (d) occurred both during summer-autumn months (August, September, October and November), and in spring (April, May). High values of total vibration doses during the summer-autumn months were associated with the performance of transport activities, soil management and harvesting root plants, of great intensity (prolonged duration of exposure, vibration of high accelerations). In spring, however, there prevailed transport activities, hay tedding and raking, disc harrowing, fertilizer spreading and chemical treatment – also emitting high values of vibration accelerations, accompanied by long-term exposure. The results of the study confirm the principle that in order to obtain a genuine and representative evaluation of the degree of whole body vibration risk among private farmers, the full production cycle should be examined, covering the period of the whole year, and all the types of agricultural and transport activities performed.

In turn, the calculated equivalent dose of daily vibration acceleration showed the highest values during 4 months of the year: April and May (0.52 m/s^2), and in August and September (0.56–0.57 m/s^2); while the lowest values were observed in January, February and December (0.25–0.27 m/s^2). The average value of this parameter, for the whole year, reached the level of 0.45 m/s^2 (below allowable values).

Earlier preliminary studies concerning mechanical vibration emitted by agricultural vehicles, conducted by the author of the presented study [26], showed that a special risk for farmers' health may be created by vibration patterns occurring on seats while performing such work activities as hay tedding and raking (0.94–1.12 m/s^2), spreading fertilizers (0.87–1.35 m/s^2), soil aggregation (0.87–1.12 m/s^2), grass mowing (1.05 m/s^2), and cultivation (0.46–0.99 m/s^2). These are work activities performed at elevated working speeds of tractors, most often over a hardened and uneven surface.

The results of studies of whole body vibration by other authors are most often presented in the form of the parameter called a vector sum of frequency-weighted acceleration (this is the root-sum-of-squares of the values for 3 directions of vibration in m/s^2). According to Boshuizen et al. [3], while driving a tractor over a hardened surface, vibration accelerations are emitted of the value 1.1 m/s^2, while wile driving over a field: 0.6 m/s^2. Bovenzi and Betta [4], and Bovenzi and Hulshof [5] obtained, according to tractor type, vibration acceleration on the level of 0.89 – 1.41 m/s^2, whereas Sandover *et al.* [22] obtained the values of 0.35–1.45 m/s^2. The data are similar to the values obtained by the author of the presented study in his first report [26].

Despite the fact that the mean values of equivalent vibration acceleration obtained in the presented study remain below allowable levels (standard: A(8) = 0.8 m/s^2), keeping in mind the occurrence of mechanical shocks in agricultural vehicles (creating risk for operator's spine), in the hygienic evaluation the registered maximum values of vibration acceleration should be considered (0.81–1.01 m/s^2), which for the majority of months exceed the quoted standard. This is confirmed by the data from literature, which evidence the hazardous effect of whole body vibration of the musculoskeletal system. Barbieri *et al.* [1], Bovenzi and Betta [4], Boshuizen *et al.* [3], and Manninen *et al.* [16] noted the occurrence of considerably more frequent back pain in tractor drivers than in the control group not exposed to whole body vibration. The occurrence of this pain increased with the vibration dose absorbed. According to Bovenzi *et al.* [4], occupational exposure to whole body vibration is accompanied by an increased risk of back pain in the lumbar region, ischias, and degenerative changes in the spine, including deformation of lumbar intervertebral discs.

The mean values of vibration accelerations obtained in the presented study exceeded the *daily exposure action values* ($A(8)_w$ = 0.5 m/s^2) in 4 months (April, May, August and September); in the case of maximum values vibration accelerations, exceeding concerned all months of the year.

Considering *daily exposure action values*, Directive 2002/44/EC of the European Parliament [7] specifies the duties of employers in the area of protection of employees against risk, which results or may result from exposure to mechanical vibration at work. The Directive obliges the employer to perform the evaluation of risk and, when needed, to perform measurements of the level of mechanical vibration to which workers are exposed. Taking into consideration technical progress and availability of the means of hazards control at the site of its occurrence, the employer should eliminate these hazards at their source or limit them to a minimum. When *daily exposure action values* are exceeded, the employer is obliged to establish and implement in practice the programme of technical and/or organizational means aimed at the limitation to a minimum of the exposure to vibration, with consideration of the following:

- other methods of work and selection of adequate working equipment, which would cause lower exposure;
- equipment which limits whole body vibration (e.g. shock absorbing seats);
- programmes for the maintenance of working equipment, workplace;
- information and training of employees in the area of safe use of working equipment;
- proper working time schedules, with breaks for rest.

CONCLUSIONS

1. The studies of the annual exposure to whole body mechanical vibration among private farmers specialising in plant production confirmed that the degree of mechanical vibration load is conditioned by both the level of the vibration transmitted from the seats of vehicles to the whole body of an operator, and the duration of exposure to the factor within a specified time interval.
2. The study showed that the highest values of the total vibration dose (d) occurred both during summer-autumn months (August, September, October and November), and in spring (April, May).
3. The calculated mean equivalent values of daily vibration acceleration showed the highest values during 4 months of the year: April and May (0.52 m/s^2), and in August and September (0.56–0.57 m/s^2); the average value of this parameter for the whole year reached the level of 0.45 m/s^2 (remained below allowable values).
4. Considering the fact of the occurrence of mechanical shocks in agricultural vehicles (high maximum accelerations values were registered: 0.81–1.01 m/s^2; exceeding the standard), and exceeding the *daily exposure action value*, proper steps should be undertaken with respect to the protection of private farmers against risk resulting from exposure to mechanical vibration while performing work activities.

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