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A Comparison between the Latest Models of Li-Ion Batteries and Petrol Chainsaws Assessing Noise and Vibration Exposure in Cross-Cutting

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Abstract: Chainsaw operators are exposed to many hazards that can lead to health problems. The two most frequently documented ergonomics threats in the use of chainsaws are noise and vibration exposure. Since the use of battery chainsaws is increasing due to the growing improvements in battery life and power, the study aims to compare the difference in terms of noise emission and vibration levels of the following two new models of chainsaws: the battery-powered Stihl MSA 300 and the petrol-powered Stihl MS 261 C-M. Black pine and European beech logs were cross-cut in order to evaluate both noise and vibration exposure. The results show that the use of battery-powered chainsaws, in comparison to the petrol one, can reduce the daily vibration exposure by more than 51% and the noise dose by 11%. The daily vibration exposure of 1.60 ms^{-2} and 1.67 ms^{-2} measured for the battery-powered chainsaw on Black pine and on European beech, respectively, is far from the daily exposure action value set by the EU directives for health and safety requirements (2.5 ms^{-2}). On the contrary, the daily noise exposure for the battery chainsaw was 93 dB(A), exceeding the upper exposure action value of 85 dB(A).

Keywords: chainsaw; battery; wood density; wood defects; hand-arm vibration; noise; ergonomics

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1. Introduction

The use of chainsaws powered by two-stroke combustion engines in forestry and pruning operations is still very common in many countries [1,2] due to its versatility and its reasonably low cost [3–6]. Many activities related to wood harvesting, agriculture, professional green maintenance, and to hobby sector are based on the use of this tool, whose danger is often underestimated. In fact, chainsaw use leads to the workers' exposure to many hazards such as cutting wounds, workload, hand-arm vibrations (HAV), exhaust fumes, noise, and wood dust [7–11]. Moreover, the work with chainsaws reports one of the highest injury frequencies [12,13], and it is often related to the onset of professional diseases in the medium and long term due to the prolonged exposure to unfavorable operational conditions. The hazards related to noise and vibrations are often wrongly undervalued by forest operators who often do not consider them as an immediate risk to their health and because the negative effects do not appear so quickly after exposure [14,15]. The symptoms related to vibration exposure in wood harvesting operations have been investigated in many studies [16,17] and are known altogether as the hand-arm vibration syndrome (HAVs). Vibrations transmitted through the chainsaw handles to the hand-arm system could cause blood flow disorders in the fingers (Vibration White Finger VWF) [1,18] and disorders of neurological functions and movements of the hand and arm [19]. In workers exposed to vibrations, the following have been detected: hands and arms numbness, fingers tingling, and worsening of the fingers' tactile perception [20,21]. These disorders generally affect the hand-arm system during and after exposure, especially during the night-time [21,22]. Other epidemiological studies [20,23–25] revealed several associations between HAV exposure and carpal tunnel syndrome and bicipital tendinitis and epicondylitis in forestry workers. The risk of developing these diseases is proportional to the frequency, amplitude, and direction of vibrations and daily exposure [26]. Furthermore, studies performed by Yovi et al. (2019) and Goglia et al. (2012) have demonstrated that other factors such as chain tension, bar length, fuel quantity in the tank, and operator's experience affect the level of the vibrations transmitted [27,28], which is also influenced by the different operations carried out (e.g., felling, delimbing, pruning, etc.) [29]. The influence of wood species on vibration emission was studied by [15,30–33]. The findings of these studies reveal that softwood species show a lower cutting resistance, which results in fewer vibrations production than hardwood species even if in conifers, as investigated by Kuvik et al. (2017) and Neri et al. (2022), the presence of wood defects (knots, scar calluses due to cracks) reduces the chainsaw performance, increasing the cutting times and the vibration levels [34,35].

Another hazard affecting forest workers during the use of chainsaws is noise exposure. High noise levels can negatively affect operators' hearing capability even with short exposures causing a temporary or permanent loss of sensitivity [36,37] and acuity [15]. The main noise sources in internal combustion chainsaws are the engine and all the mechanical processes involved. The ejection of exhaust fumes and the movement of the saw chain over the guide bar too, affect the noise production [11], as the chainsaw power and its design [33].

In recent years the increasing attention to the operator's health and to environmental protection has led to the development of lithium-ion battery chainsaws by the manufacturers of forestry and gardening tools [18,38]. This new power supply method shows the following advantages in terms of the operator's health [39–41]: in fact, the replacement of the alternative movement generated by the internal combustion engine with a rotational movement, characteristic of the battery engine, allows the elimination of the processes that most affect the production of noise and vibrations such as, for example, the piston and its back-and-forth movement [11]. Concerning this aspect, Huber (2021) has demonstrated that battery-powered chainsaws present a reduction of 45% of daily vibration exposure and 78,4% of noise exposure compared to an internal combustion chainsaw [33]. This minor exposure is also due to immediately switching off the battery chainsaw after the throttle trigger is released during the non-operative time, in contrast to a petrol chainsaw that passes to idle speed continuing the emissions of noise and vibrations [40].

Even small maintenance, the elimination of exhaust fumes, and the absence of cables are other advantages of battery chainsaws [42]. In addition, Li-ion batteries can now be recycled with an efficiency of 97% w/w of the precious components [43,44]. Despite these positive aspects, during hard-working conditions, battery-powered chainsaws still reveal some problems, such as insufficient battery capacity [45] and the risk of overheating of the battery pack, with possible consequences on productivity [46] and as highlighted by Huber (2021) and Poje et al. (2018) [33,40] these chainsaws present values of noise and vibrations still very close to limits set by EU Directive 2003/10 and Directive 2002/44/EC. For these reasons, petrol chainsaws are currently largely preferred in forest operations, while electric and battery ones are almost exclusively used for professional green maintenance or for hobby [18]. Nevertheless, considering that the use of battery chainsaws is increasing in forest operations due to the growing improvements in battery life and power, it is important to understand the current potential of an effective use of battery chainsaws in forestry, also considering the potential benefits in terms of ergonomics improvement. Under this perspective, this study aims to compare the difference in terms of noise emission and vibration levels of the following two of the latest models of chainsaws, similar in terms of weight and power: the new Stihl MSA 300 battery-powered and the Stihl MS 261 C-M petrol-powered, very common among all professional forest workers, during conifer and broadleaf cross-cutting, in Central Italy. Black pine and European beech were cross-cut to evaluate the influence of the wood density and wood defects on the vibrations production.

2. Materials and Methods

2.1. Occupational Exposure Limits

The procedures related to the measurement and evaluation of vibration at the workplace are described by the EU Directive 2002/44/CE "Vibration", which concerns the ISO 5349-1:2004 and ISO 5349-2:2015 Standards [47,48]. These regulations include several amendments, changes, and recommendations such as the risk assessment, the employees' information, the education and training, and the implementation of a specific program focused on the vibration exposure reduction. The EU Directive states that vibration must be investigated measuring the frequency-weighted acceleration on the machine handles. The exposure evaluation is calculated considering the standard 8 h working day exposure level A(8), and it must consider the highest vibration value measured on either handle. The following two different values of daily exposure are considered by the EU Directive in order to identify the actions to be taken by the employer: the action value (2.5 ms^{-2}) and the daily exposure limit value (5 ms^{-2}). If the daily exposure is under the Action Level, the possibility of contracting vibration-related diseases is low. Over the Limit Value, this risk is significantly increased. If the vibration exposure A(8) exceeds the action level of 2.5 ms^{-2}, the company must perform a risk assessment procedure and must implement the necessary operational precautions to control and contain the vibration-related risk.

Considering the hazard associated with noise exposure, according to the EU Directives, the peak sound pressure and the daily noise level must be considered to define the exposure limits. The Directive 2003/10/EC stated that the daily exposure must not exceed 87 dB(A) or 140 dB(C) in any case and establishes the upper action value at 85 dB(A) or 137 dB(C), and the lower action value at 80 dB(A) or 135 dB(C).

2.2. Sampling and Analysis

Cross-cutting operations with battery and petrol chainsaw were carried out at the landing in the Vallombrosa Forest (province of Florence, Tuscany, Italy, 43°44′04.4″ N 11°33′22.2″ E). The study compared the following two new models of chainsaws, with comparable characteristics: the Stihl MSA 300 battery-powered and the Stihl MS 261 C-M petrol-powered (Figure 1), during conifer and broadleaf cross-cutting. The Stihl MS261 C-M was considered because it is one of the most common chainsaws used by professional forest workers. In fact, Stihl MS261 C-M and equivalent models are commonly used to cut and delimb small and medium diameters and branches. The technical specifications of each chainsaw, according to the manufacturer declarations, are shown in Table 1. The two chainsaws were chosen from the same brand in order to use the same type of saw bar and chain among those recommended. In fact, during the study, both saws were equipped with the same chain type sharpened by the manufacturer and guide bar with a sprocket nose. Chainsaws were not factory-fresh, but of low operational use, well-maintained, and in perfect technical condition.

Two different tree species, Black pine—BP (*Pinus nigra* Arnold) and European beech—EB (*Fagus sylvatica* L.), were selected for cross-cutting to evaluate the influence of wood density and wood defects on the vibration's emission. All the wood slices cut were photographed to check the eventual presence of wood defects to analyze their influence on vibrations production. The test site was located close to electric network plugs to facilitate battery recharge. BP and EB logs with diameters between 22 and 33.5 cm were cross-cut for the test. Wood basic density was measured as stated in ISO 13061-2:2014 [49] and reported as the ratio between oven-dry weight and fresh volume of samples collected from three discs produced during the cross-cutting operation for each log. Basic density resulted in 490 kg m^{-3} for the Black pine and 556 kg m^{-3} for the European beech. Logs were firstly positioned horizontally at about 1 m from the ground using wooden supports (two logs), a crane was used to move and hold the logs, then measurements were recorded during the cross-cutting. The cut was performed from the top of the log following a vertical direction and obtaining slices of wood (Figure 2) of about 2 cm thick. The tests were carried out by one qualified forest worker with long-lasting experience in chainsaw use (more than 10 years).

(**a**) (**b**)

Figure 1. The petrol chainsaw Stihl MS 261 C-M (**a**) and the Li-Ion battery chainsaw Stihl MSA 300 (**b**).

Table 1. Technical specifications of the two chainsaws.

	Stihl MSA 300	**Stihl MS 261 C-M**
Power	3.0 kW	3.0 kW
Saw-bar length	40 cm	40 cm
Chain type	Half-chisel	Half-chisel
Chain pitch	0.325″ (0.8255 cm)	0.325″ (0.8255 cm)
Drive-link thickness	1.3 mm	1.3 mm
Number of drive links	67	67
Fuel supply	Electricity (battery)	Mixed (gasoline + oil)
Battery/Fuel type	AP500S	Stihl MotoMix
Maximum chain speed (ISO 11681)	30 m s^{-1}	25.6 m s^{-1}
Total weight *	7.7 kg	6.9 kg

* Including saw bar, chain, and battery or fuel and chain lubricant.

Figure 2. The measurements during cross-cutting.

The time required to perform a valid vibration measurement was one minute of cutting, therefore including at least 5 slices per measure. In total, considering one operator, two chainsaws, and two tree species, 196 measures were collected. The exposure of forest operators to HAV was measured following the ISO 5349:2001 standard. The daily exposure values of HAV were calculated considering the A(8) frequency-weighted acceleration measures and combining the values measured on the three axes on each handle. The analysis was carried out according to ISO 5349–1 [47], which describes the right procedures to evaluate the vibration exposure considering the three orthogonal axes (x, y, z). It specifies the weighting frequency and the band filters to allow a regular measurement comparison. The results enable us to evaluate the vibration effects on the hand considering the average frequency range of the one-third octave band (6.3 Hz to 1250 Hz) as established by the standard ISO 5349-2: 2015 [48]. Moreover, the standard also specifies the orientation of the Cartesian axes on which the measures will be taken. The reference scheme starts from the beginning of the third metacarpal sector, the "z" axis being parallel to the hand axis, the "y" axis perpendicular to the plane bounded by the "x" and "z" axes in left orientation. In accordance with ISO 5349-1 [47], A(8) was calculated using the following equation:

$$A(8) = A_{(w)sum}\ (\ \frac{Te}{8}\ )^{1/2}$$

where:

- T_e: total daily vibration exposure (8 h in this study);
- $A_{(w)sum}$: $(a^2{}_{wx} + a^2{}_{wy} + a^2{}_{wz})^{1/2}$;
- a_{wx} a_{wy} a_{wz}: root average square values of frequency-weighted acceleration (ms^{-2}) on the three axes (Figure 3).

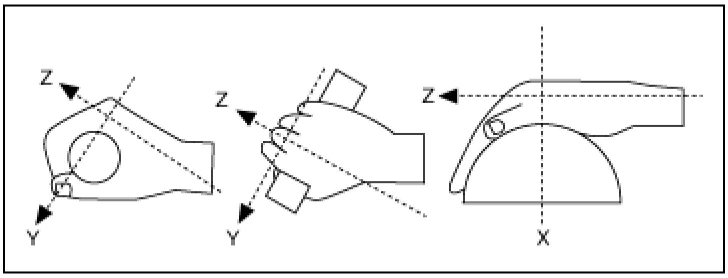

Figure 3. Reference scheme of the three orthogonal axes (*x*, *y*, *z*) for hand-arm vibration measurement [44].

Hand-arm vibration (HAV) was measured using a six-channel human vibration meter Svantek mod. 106 (Figure 4), equipped with two triaxial accelerometers SV 105A (Svantek, with a sensitivity of 10 mV g^1—Figure 5).

Figure 4. Six-channels human vibration meter Svantek mod. 106.

Figure 5. Handgrip triaxial accelerometers SV 105A, Svantek.

These devices were chosen according to the standards ISO 2631-1,2,5, ISO 5349, and the directive 2002/44/EC, and it allows simultaneous hand-arm vibration measurements on both operator's hands. Vibrations on both hands were analyzed and accelerations were measured. The accelerometers were positioned on the handle (Figure 5) in the middle of its grip area, in order to obtain a more representative evaluation of the vibrations transmitted. Following the standards ISO 5349-1:2001 and ISO 5349-2:2002, vibrations were measured on the three orthogonal axes, and the values were analyzed considering the frequency range included in the octave bands from 8 Hz to 1000 Hz [50,51].

In parallel with the vibrations analysis, the investigation on noise was performed to find the equivalent continuous A-weighted sound pressure level (L_{Aeq}). The noise analysis was conducted following the EU Directive 2003/10/EC [52] and the following standards: ISO 9612:2011 [53] and ISO 11201:2010 [54], using a noise meter and microphone. The "task-based measurement" method was selected considering the options indicated by ISO 9612:2011 [51] because it suited the test design better than the other possibilities. Noise levels were measured using the class 1 noise level meters DeltaOHM 2010, Brüel&Kjær 2250, with microphone positioned at operator's ear level (Figure 4). The noise load was investigated measuring the following: (i) equivalent continuous A-weighted sound pressure level (L_{Aeq}) with a full sound frequency spectrum in 1/3 octave bands; (ii) a maximum value of the C-weighted immediate sound pressure (LCpeak). Noise measurements were collected during the cuts. During noise measurement, there were no other machines operating. The noise exposure was investigated considering the standard 8 h working day exposure level (L_{EX}, 8 h). L_{EX}, at 8 h, was computed by the following equation:

$$L_{EX}(8\,\mathrm{h}) = 10\log\left[\frac{1}{T_0}\sum_{i=1}^{n} T_i 10^{0,1L_i}\right]$$

where:

- T_i is the daily exposure time in minutes (480 min in this study);
- L_i is the continuous equivalent level (L_{Aeq}) of the noise source;
- T_0 is the daily working time of 8 h.

2.3. Statistical Analysis

Vibration A(8) and noise daily exposure values measured during the cuts were analyzed to evaluate the differences between the two chainsaws. Analyses were computed with the open-source statistical software R version 4.2.3 [55]. Normality was checked with the Shapiro test, and homoscedasticity of variance with the Bartlett test to identify the suitable statistical method to analyze the differences in both vibration and noise exposures. The data resulted non-normal distributed and heteroscedasticities; therefore, a multiple comparisons and simultaneous confidence intervals test was applied. In order to use this non-parametric method, the analysis was conducted using the standard R packages and "nparcomp" package [56]. The function nparcomp computes the estimator of non-parametric relative contrast effects, simultaneous confidence intervals for the effects, and simultaneous p-values based on special contrasts, Tukey in this case. In addition, the relation between vibration exposure with the presence of wood defects was checked using ANOVA and HDS post hoc test due to the normal distribution.

3. Results

During the study, 196 measures (49 per chainsaw per wood species) were recorded during cross-cutting. Despite the presence of wood defects (i.e., knots, scar calluses due to cracks) in the wood slices, the vibration exposure was not affected. No significant differences were found in the comparison between vibration exposure values with and without wood defect per species and chainsaw tested. In detail, for the petrol-powered chainsaw, the recorded vibration exposure values were as follows: in presence of wood defects 3.26 ms^{-2} in EB and 3.04 ms^{-2} in BP, in absence of wood defects 3.19 ms^{-2} in EB and 2.99 ms^{-2} in BP. Regarding the battery-powered chainsaw, the recorded vibration exposure values were as follows: in presence of wood defects 1.57 ms^{-2} in EB and 1.52 ms^{-2} in BP, in absence of wood defects 1.53 ms^{-2} in EB and 1.49 ms^{-2} in BP. Daily exposure values to vibrations A(8) for both battery and petrol chainsaws are shown in Figure 6. Considering the battery chainsaw, a significant difference between the median values of acceleration was recorded in comparison to the petrol chainsaw. The mean daily exposure values of battery chainsaw (Stihl MSA 300) were 51% lower than petrol chainsaw (Stihl MS 261 C-M), 55% and 46% lower for the left handle and for the right handle, respectively. In fact, the Stihl MSA 300 reported the lowest values of acceleration for both handles.

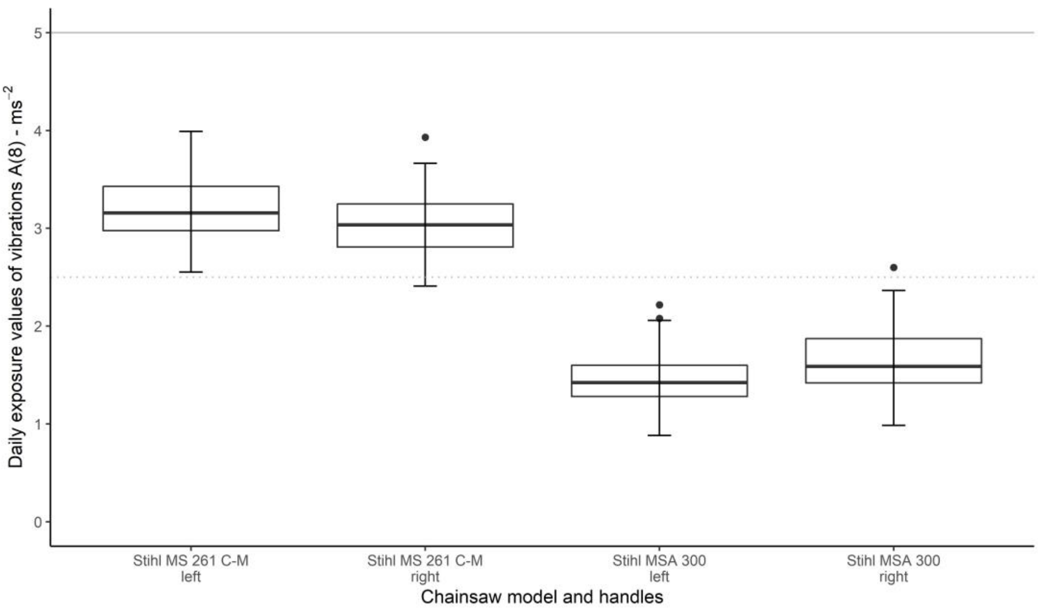

Figure 6. The graphical representation of the vibration exposure values (A(8)) of the tested chainsaws was recorded for the left and right handles. Horizontal grey lines represent, respectively, the following: action value (dotted) and daily exposure limit (continuous).

Daily exposure values to vibration A(8) for both wood species and chainsaw models are shown in Table 2. Analyzing the effect of wood species on the vibration exposure on both chainsaws, the Stihl MSA 300 resulted in similar mean vibration values in EB and BP for both handles (Figure 7). On the contrary, the Stihl MS 261 C-M was affected in terms of daily vibration exposure depending on the wood species. For the petrol chainsaw, a significant difference was recorded between EB and BP, with a ~10% higher vibration in EB for the right handle. The statistical analysis findings (Figure 7) confirmed the differences found in the daily vibration exposure values. Moreover, based on this analysis, it is clear that the Stihl MSA 300 emitted significantly lower values than Stihl MS 261 C-M in all analyzed comparisons.

Table 2. Daily vibration exposure values (A(8)) reported for each chainsaw model recorded for the left and right handles in different wood species.

Vibration Daily Exposure (A(8) ms^{-2})							
	Handle	**n**	**Min**	**Median**	**Mean**	**SD**	**Max**
Stihl MSA 300	left	49	1.11	1.42	1.41	0.19	1.86
Black pine	right	49	1.19	1.57	1.60	0.28	2.34
Stihl MSA 300	left	49	0.88	1.40	1.45	0.30	2.22
European beech	right	49	0.99	1.67	1.67	0.38	2.60
Stihl MS 261 C-M	left	49	2.55	3.09	3.12	0.31	3.99
Black pine	right	49	2.52	2.88	2.90	0.21	3.42
Stihl MS 261 C-M	left	49	2.66	3.24	3.30	0.33	3.89
European beech	right	49	2.41	3.24	3.21	0.30	3.93

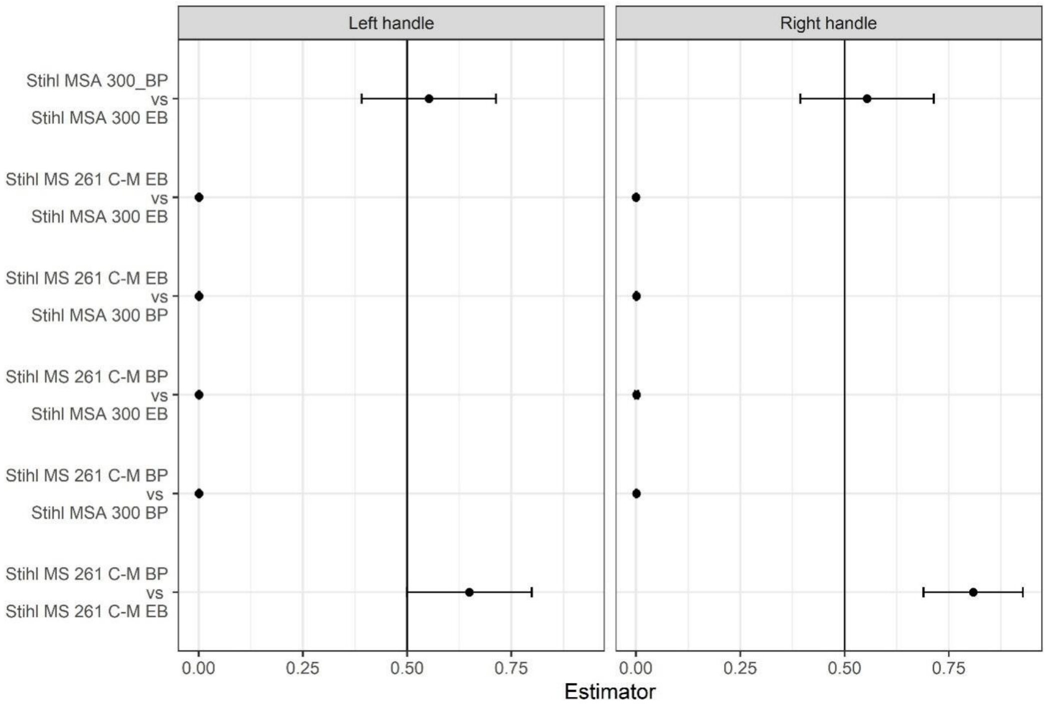

Figure 7. The comparison between the different chainsaw models in different wood species on vibration daily exposure (A(8) ms^{-2}) recorded the following: results of multiple comparisons and simultaneous confidence intervals test using Tukey contrasts. Symbols (black dots) represent the estimators of each compared category, and the bars show the effect size (±95% confidence intervals). The pair-wise comparisons of relative contrast effects are significantly different when the bar does not overlap 0.50.

The noise measurements are shown in Figure 8 (L_{Aeq}). Consequently, based on these values, the daily exposure level (L_{EX}, 8 h) can be calculated. The findings showed the lower values for the Stihl MSA 300 chainsaws than for the Stihl MS 261 C-M. The "L_{EX}, 8 h" average values were 93 dB for Stihl MSA 300 and 105 dB for Stihl MS 261 C-M (Table 3).

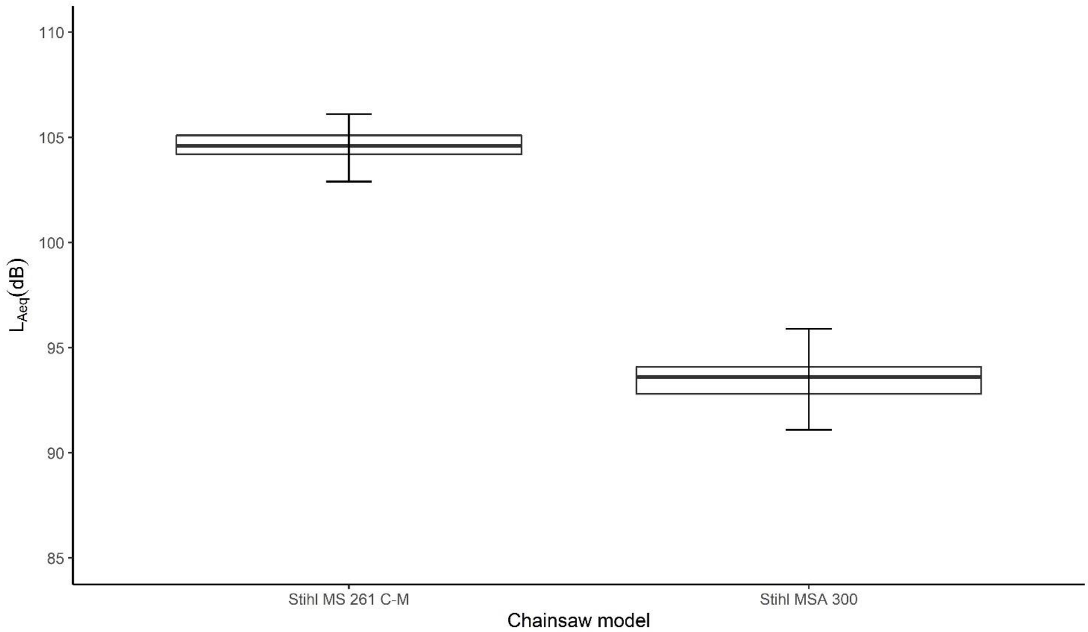

Figure 8. The graphical representation of the noise daily exposures (L_{EX}) of the tested chainsaws.

Table 3. Noise daily exposures (L_{EX}) reported for each chainsaw model recorded on different wood species.

Noise Measurements (L_{EX})							
	Species	**n**	**Min**	**Median**	**Mean**	**SD**	**Max**
Stihl MSA 300	*Black pine*—BP	49	91	93	93	0.8	96
	European beech—EB	49	92	94	94	1.1	96
Stihl MS 261 C-M	*Black pine*—BP	49	103	105	105	0.6	106
	European beech—EB	49	104	105	105	0.7	106

4. Discussion

The aim of this study was to compare the hand-arm vibration and noise exposure produced by two new models of Li-Ion Batteries and Petrol Chainsaws during Conifer and Broadleaf Cross-Cutting operations. The comparable technical specifications of the two chainsaw models and the presence of a single worker operating during the analysis allowed the direct comparison of noise and vibration exposure between the two chainsaws. However, despite the similar characteristics, the MSA 300 has an advantage of about 15% over the MS 261 C-M in relation to the chain speed (considering the maximum speed for an unloaded chain, as declared by the manufacturer). To analyze the influence of the different chain speeds between the two models on the vibration and noise exposure is hard, especially taking into account that one chainsaw is battery-powered. However, in a previous study that compared only petrol-powered chainsaws [33], the findings showed that the higher performance resulted in higher vibration and noise exposure. Moreover, the influence of the different chainsaws' weight is hard to evaluate. Usually, powerful and light machines are preferred for many work tasks, as they tire the operator less. However, low machine weight often results in high levels of vibration emitted [33]. Since the MSA 300 is, depending on the level of chain lubricant, about 10% heavier than the MS 261 C-M, the lighter machine (MS 261 C-M) has a disadvantage regarding the vibrations emission, even if its lightness is positively rated.

4.1. Vibration Exposure

The findings revealed that the MSA 300 resulted in a strong lower vibrations emission in comparison to the petrol-powered machine MS 261 C-M and that the average acceleration values measured for battery-powered chainsaws are lower than those recorded for petrol-powered chainsaws in recent studies [40]. The different daily exposure values recorded for the two chainsaws are probably due to the different power sources being equal to the cutting device specifications and the teeth sharpening level. The presence of the anti-vibration device in MSA 300, which is not included in previous battery models [18], positively contributed to the high difference measured in terms of vibrations between battery and petrol chainsaws. In this sense, manufacturers should include anti-vibration systems in all their battery models. Moreover, it is important to highlight that sharp teeth (new chain) present 7.5% less vibration transmissibility with respect to chain teeth presenting sharpening anomalies [57]. Following the standard ISO 5349-2, the vibration exposure investigation must be performed considering the highest value measured between the two handles of the chainsaw. In this study, the maximum values of acceleration recorded were under the daily exposure limit of 5 m s^{-2} set by the EU Directive 2002/44/CE for the battery-powered chainsaw. The results were also in accordance with the first findings published by Poje et al. [40], which compared battery and petrol-powered chainsaws. Analyzing the A(8) values (Table 2), different values were recorded between the left and right handles of both chainsaws. The MS 261C-M showed higher vibration values for the left handle, while the MSA 300 showed higher values for the right one. Similar differences were already found by a previous study focused on endothermic chainsaws [58]. Most likely the absence of the piston under the left handle of the battery chainsaw could be the cause for the lower vibrations measured for the left handle on this machine. In general, the main reason of the lower vibration production for the battery chainsaw consists of the technical characteristics of the engine. First of all, the explosion phase, characteristic of endothermic engines, is absent in battery-powered machines. Secondly, the rotational movement characteristic of electric engines takes the place of the piston-directional movement in the internal combustion engine. The absence of directional forces leads to a reduction of the vibration transmitted [59]. Moreover, within the availability of chainsaw battery models, the constructional characteristics of the MSA 300 reduced a lot the vibration exposure, being the MSA 300 the first model of battery chainsaw with an anti-vibration system (springs and inserts that separate the handles from the engine and cutting device).

4.2. Noise Exposure

Using the battery chainsaw, the noise exposure is strongly lower than working with the petrol chainsaw. Considering the noise measurements (LAeq) reported in Figure 8, the daily exposure level (LEX, 8 h) can be easily calculated. The "LEX, 8 h" values were 93 dB(A) for Stihl MSA 300 and 105 dB(A) for Stihl MS 261 C-M. The significant decrease in noise exposure when using a battery-power chainsaw is due to the absence of the combustion engine. The noise emission due to the exhaust system is the loudest part of a traditional petrol-powered chainsaw. The other sources of noise are due to the fuel intake phase and the chain. Another factor that should be considered in a broader investigation on noise is that the battery chainsaw, when the operator is not sawing, does not produce any emissions (noise, exhaust fumes, nor vibrations) while the traditional petrol chainsaw is still running in idle mode producing noise and exhaust gases. In this sense, the findings confirm the health and safety benefits of using battery-powered chainsaws in comparison to traditional petrol chainsaws. Unfortunately, despite the significantly better performance of the battery chainsaw in comparison with the petrol one in terms of noise, the eight-hour exposure still exceeds the limit values, maintaining the use of personal protective equipment mandatory.

4.3. Influence of the Wood Species and Defects

Evaluating the influence of the wood species on the vibration exposure, results confirmed the relation the higher the wood density, the higher the vibrations emission [28,30] only in the case of the MS 261 C-M, which showed a ~10% higher vibrations for EB on the right handle. The battery-powered chainsaw did not show a similar behavior, producing similar vibration mean values for both wood species and for both handles. Despite the presence of wood defects in the wood slices cut, the vibration exposure for both chainsaws and for both wood species was not affected. Rather it was expected that, in relation to the wood species, the presence of wood defects would have reduced the cutting efficiency of the chainsaws, increasing consequently the level of vibrations transmitted. This aspect, as demonstrated by Neri et al. (2022), was more evident in Black pine since the presence of wood defects did not affect the cutting efficiency of European beech in that study. This behavior on Black pine was expected in the reason of the higher density of knots that causes a consequent decrease in the cutting performance [31,34]. Most likely, in this study, the effect of wood defects on the vibration emission was diluted on the number of slices cut (5–6) in the time required (1 min) to record a valid measurement for the vibration exposure evaluation, and it resulted null.

4.4. Manufacturer's Declarations

The vibrations and noise emission levels reported in the chainsaw's technical manuals are shown in Table 4. Considering vibrations, the values measured in this study are slightly different from those indicated in the user manual. These differences may be due to the application of the following two different standards: the UNI EN ISO 5349 [47,48] applied in this study to measure the vibration levels in working conditions, and the standards (e.g., ISO 22867:2011—EN62841-4-1) [60] used by the manufacturer to measure vibrations emission under laboratory conditions. Therefore, the type of chain used, the type of wood cut, and the number of samples may have been different in the two assessments. However, similar values between the two handles for both chainsaws were recorded considering the manufacturer's declarations and our findings. These aspects could be investigated more deeply to better understand the operator's behavior in handling the machine on the vibration emission. The noise evaluation revealed that, for the battery chainsaw, the values are in accordance with the manufacturer's declarations. The noise levels measured for the petrol chainsaw were at least 12 dB(A) higher than the battery model, as stated in a previous study [40].

Table 4. Comparison between the noise and vibration levels measured and declared by the manufacturer.

	Noise dB(A) L_{EX},8 h		Vibration A(8) ms^{-2}			
			Left Handle		Right Handle	
Chainsaw Model	Declared	Measured	Declared	Measured	Declared	Measured
Stihl MSA 300	93	93	1.5	1.4	1.6	1.6
Stihl MS 261 C-M	104	105	3.5	3.2	3.5	3.1

4.5. Operating Conditions

Previous studies [45,61] investigated the productivity of several work tasks using professional battery chainsaws. The findings reveal that the latest models of battery chainsaws achieved good levels of reliability and productivity in small-scale forestry operations, and their use is highly recommended in those cases where working restrictions related to noise and exhaust exposure are established. Professional battery chainsaw results also indicated for tree processing at the landing in case of whole tree extraction. Theoretically, considering the lower emissions in terms of vibrations, noise, and exhaust fumes, the use of battery chainsaws in real forest operations would be a better alternative than petrol-powered ones. In practice, despite these positive aspects, battery chainsaws are not yet ready for a professional use in forestry due to the need to frequently recharge the batteries. This is the main limiting factor. In the forest, the only solution consists in having a series of batteries available to cover the entire 8 h working day. In other working contexts, the use of battery-powered chainsaws faces fewer problems than in the forest context, and it is very common in arboriculture and in pruning operations in urban areas. Here the proximity to the electricity grid for recharging the batteries and the reduction of some risk factors make it an increasingly widespread tool.

5. Conclusions

In this study, the noise and vibration exposure during cross-cutting operations on softwood and hardwood logs by battery and petrol-powered chainsaws was investigated. The machines were chosen between the latest professional chainsaw models of medium size. The Li-Ion battery chainsaw clearly recorded lower emissions of both noise and vibrations. The fast development of battery tools in forest operation is expected to increase, and powerful batteries are under the planning and development phase being the battery duration as the evident limiting factor. Nowadays, these machines represent an alternative to traditional petrol chainsaws for pruning and thinning operations and can be safely used by those people that are exposed to professional diseases related to noise and vibrations. From an operational point of view, in the forestry operations described above, the battery-powered chainsaws can be often switched off, while petrol chainsaws are usually left running, still making noise, vibrations, and exhaust fumes. Therefore, considering the health and safety recommendations, battery-powered chainsaws should be preferred over petrol-powered ones whenever possible. Therefore, to prevent the onset of occupational diseases related to vibration exposure and following the risk assessment, the use of personal protection equipment is mandatory, such as the use of anti-vibration gloves. Their use should be considered as an additional measure together with the proper chainsaw maintenance and sharpening to contribute to a vibration reduction. The main action of gloves is to protect the hands from mechanical risks, keeping them warm and dry; they also can reduce the risks associated with hand-arm vibrations improving the blood circulation in the hands and fingers. Since the daily noise exposure also exceeds the maximum exposure action value, hearing protection is required even for professional battery-powered chainsaws.

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References

1. Albizu-Urionabarrenetxea, P.; Tolosana-Esteban, E.; Roman-Jordan, E. Safety and Health in Forest Harvesting Operations. Diagnosis and Preventive Actions. A Review. *For. Syst.* **2013**, *22*, 392–400. [CrossRef]
2. Picchio, R.; Blasi, S.; Sirna, A. Survey on Mechanization and Safety Evolution in Forest Works in Italy. In Proceedings of the International Conference Ragusa SHWA2010, Ragusa Ibla Campu, Italy, 16–18 September 2010.

3. Liepiņš, K.; Lazdiņš, A.; Liepiņš, J.; Prindulis, U. Productivity and Cost-Effectiveness of Mechanized and Motor-Manual Harvesting of Grey Alder (*Alnus Incana* (L.) Moench): A Case Study in Latvia. *Small-Scale For.* **2015**, *14*, 493–506. [CrossRef]
4. Russell, F.; Mortimer, D. *A Review of Small-Scale Harvesting Systems in Use Worldwide and Their Potential Application in Irish Forestry*; COFORD: Dublin, Ireland, 2005; ISBN 190269645X.
5. Spinelli, R.; Nati, C.; Magagnotti, N. Biomass Harvesting from Buffer Strips in Italy: Three Options Compared. *Agrofor. Syst.* **2006**, *68*, 113–121. [CrossRef]
6. Ottonelli, J.; Brandelero, C.; Werner, V.; Schlosser, J.F.; Farias, M.S. Estado de Uso e Conservação de Motosserras Com Motores de Combustão Interna. *Tecno-Lógica St. Cruz Do Sul* **2020**, *24*, 196–201. [CrossRef]
7. Cheţa, M.; Marcu, M.V.; Borz, S.A. Workload, Exposure to Noise, and Risk of Musculoskeletal Disorders: A Case Study of Motor-Manual Tree Feeling and Processing in Poplar Clear Cuts. *Forests* **2018**, *9*, 300. [CrossRef]
8. Calvo, A. Musculoskeletal Disorders (MSD) Risks in Forestry: A Case Study to Suggest an Ergonomic Analysis. *Agric. Eng. Int. CIGR Ejournal* **2009**, *9*, 1–9.
9. Marchi, E.; Neri, F.; Cambi, M.; Laschi, A.; Foderi, C.; Sciarra, G.; Fabiano, F. Analysis of Dust Exposure during Chainsaw Forest Operations. *IForest* **2017**, *10*, 341–347. [CrossRef]
10. Neri, F.; Foderi, C.; Laschi, A.; Fabiano, F.; Cambi, M.; Sciarra, G.; Aprea, M.C.; Cenni, A.; Marchi, E. Determining Exhaust Fumes Exposure in Chainsaw Operations. *Environ. Pollut.* **2016**, *218*, 1162–1169. [CrossRef]
11. Kovác, J.; Krilek, J.; Dado, M.; Beňo, P. Investigating the Influence of Design Factors on Noise and Vibrations in the Case of Chainsaws for Forestry Work. *FME Trans.* **2018**, *46*, 513–519. [CrossRef]
12. Laschi, A.; Marchi, E.; Foderi, C.; Neri, F. Identifying Causes, Dynamics and Consequences of Work Accidents in Forest Operations in an Alpine Context. *Saf. Sci.* **2016**, *89*, 28–35. [CrossRef]
13. Klun, J.; Medved, M. Fatal Accidents in Forestry in Some European Countries. *Croat. J. For. Eng.* **2007**, *28*, 55–62.
14. Monarca, D.; Biondi, P.; Cecchini, M.; Santi, M.; Guerrieri, M.; Colantoni, A.; Colopardi, F. Transmission of Vibrations from Portable Agricultural Machinery to the Hand-Arm System (HAV): Risk Assessment and Definition of Exposure Time for Daily Action and Exposure Limits. In Proceedings of the "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems" International Conference, Ragusa, Italy, 15–17 September 2008; ElleDue. ISBN 978-88-903151-1-4.
15. Papandrea, S.F.; Cataldo, M.F.; Zimbalatti, G.; Grigolato, S.; Proto, A.R. What Is the Current Ergonomic Condition of Chainsaws in Non-Professional Use? A Case Study to Determine Vibrations and Noises in Small-Scale Agroforestry Farms. *Forests* **2022**, *13*, 1876. [CrossRef]
16. Barnes, R.; Longley, E.O.; Smith, A.R.B.; Allen, J.G. Vibration Disease. *Med. J. Aust.* **1969**, *2*, 259. [CrossRef]
17. Miura, T.; Kimura, K.; Tominaga, Y.; Kimotsuki, K. On the Raynaud's Phenomenon of Occupational Origin Due to Vibrating Tools—Its Incidence in Japan. *Rep. Inst. Sci. Labour Tokio Jpn.* **1966**, *65*, 1–11.
18. Neri, F.; Laschi, A.; Foderi, C.; Fabiano, F.; Bertuzzi, L.; Marchi, E. Determining Noise and Vibration Exposure in Conifer Cross-Cutting Operations by Using Li-Ion Batteries and Electric Chainsaws. *Forests* **2018**, *9*, 501. [CrossRef]
19. Matache, M.G.; Munteanu, M.; Dumitru, D.N.; Epure, M. Evaluation of Hand Transmitted Chainsaw Vibrations during Wood Cutting. In Proceedings of the E3S Web of Conferences; EDP Sciences, Constanta, Romania, 26–27 June 2020; Volume 180, p. 3013.
20. Brammer, A.J.; Pyykkö, I. Vibration-Induced Neuropathy: Detection by Nerve Conduction Measurements. *Scand. J. Work. Environ. Health* **1987**, *13*, 317–322. [CrossRef]
21. Seppäläinen, A.M. Peripheral Neuropathy in Forest Workers. A Field Study. *Work Environ Health* **1972**, *9*, 106–111.
22. Färkkilä, M.; Aatola, S.; Starck, J.; Pyykko, I.; Korhonen, O. Vibration Induced Neuropathy among Forest Workers. *Acta Neurol. Scand.* **1985**, *71*, 221–225. [CrossRef]
23. Bovenzi, M.; Giannini, F.; Rossi, S. Vibration-Induced Multifocal Neuropathy in Forestry Workers: Electrophysiological Findings in Relation to Vibration Exposure and Finger Circulation. *Int. Arch. Occup. Environ. Health* **2000**, *73*, 519–527. [CrossRef]
24. Koskimies, K.; Farkkila, M.; Pyykko, I.; Jantti, V.; Aatola, S.; Starck, J.; Inaba, R. Carpal Tunnel Syndrome in Vibration Disease. *Br. J. Ind. Med.* **1990**, *47*, 411–416. [CrossRef]
25. Bovenzi, M.; Zadini, A.; Franzinelli, A.; Borgogni, F. Occupational Musculoskeletal Disorders in the Neck and Upper Limbs of Forestry Workers Exposed to Hand-Arm Vibration. *Ergonomics* **1991**, *34*, 547–562. [CrossRef]
26. Dos Santos Depoi, J.; Brandelero, C.; Werner, V.; Schlosser, J.F.; Russini, A.; de Vargas, F. Hand-Arm Vibration in Different Operating Conditions with a Chainsaw. *Floresta* **2022**, *52*, 74–82. [CrossRef]
27. Yovi, E.Y.; Yamad, Y. Addressing Occupational Ergonomics Issues in Indonesian Forestry: Laborers, Operators, or Equivalent Workers. *Croat. J. For. Eng.* **2019**, *40*, 351–363. [CrossRef]
28. Goglia, V.; Suchomel, J.; Žgela, J.; Đukić, I. Forestry Workers' Expossure to Vibration in the Context of Directive 2002/44/EC. *Šumarski List* **2012**, *136*, 283–288.
29. Staněk, L.; Neruda, J.; Mergl, V.; Kotek, T. Difference in the Magnitude of Power Saw Vibrations Affecting the Operator during Forest Felling. *Cent. Eur. For. J.* **2023**, *69*, 59–67. [CrossRef]
30. Rottensteiner, C.; Tsioras, P.; Stampfer, K. Wood Density Impact on Hand-Arm Vibration. *Croat. J. For. Eng.* **2012**, *33*, 303–312.
31. Marenče, J.; Mihelič, M.; Poje, A. Influence of Chain Filing, Tree Species and Chain Type on Cross Cutting Efficiency and Health Risk. *Forests* **2017**, *8*, 464. [CrossRef]
32. Landekić, M.; Bačić, M.; Pandur, Z.; Šušnjar, M. Vibration Levels of Used Chainsaws. *Forests* **2020**, *11*, 249. [CrossRef]

33. Huber, M.; Hoffmann, S.; Brieger, F.; Hartsch, F.; Jaeger, D.; Sauter, U.H. Vibration and Noise Exposure during Pre-Commercial Thinning Operations: What Are the Ergonomic Benefits of the Latest Generation Professional-Grade Battery-Powered Chainsaws? *Forests* **2021**, *12*, 1120. [CrossRef]
34. Kuvik, T.; Krilek, J.; Kováč, J.; Štefánek, M.; Dvořák, J. Impact of the Selected Factors on the Cutting Force When Using a Chainsaw. *Wood Res.* **2017**, *62*, 807–814.
35. Neri, F.; Laschi, A.; Marchi, E.; Marra, E.; Fabiano, F.; Frassinelli, N.; Foderi, C. Use of Battery-vs. Petrol-Powered Chainsaws in Forestry: Comparing Performances on Cutting Time. *Forests* **2022**, *13*, 683. [CrossRef]
36. Dixon, W. Effects of High Intensity Sound. In *Handbook of Acoustics*; Crocker, M.J., Ed.; Wiley & Sons Inc: Hoboken, NJ, USA, 1998; ISBN 978-0-471-25293-1.
37. Neitzel, R.; Yost, M. Task-Based Assessment of Occupational Vibration and Noise Exposures in Forestry Workers. *Am. Ind. Hyg. Assoc. J.* **2002**, *63*, 617–627. [CrossRef] [PubMed]
38. Poje, A.; Mihelič, M. Influence of Chain Sharpness, Tension Adjustment and Type of Electric Chainsaw on Energy Consumption and Cross-Cutting Time. *Forests* **2020**, *11*, 1017. [CrossRef]
39. Hawker, A. Comparison of Hand-Arm Vibration Emissions of Battery Powered Tools and Tools of Other Power Sources. In Proceedings of the Conference on Human Responses to Vibration, Edinburgh, Scotland, 24–26 September 2019; Volume 24, p. 77.
40. Poje, A.; Potočnik, I.; Mihelič, M. Comparison of Electric and Petrol Chainsaws in Terms of Efficiency and Safety When Used in Young Spruce Stands in Small-Scale Private Forests. *Small-Scale For.* **2018**, *17*, 1–12. [CrossRef]
41. Colantoni, A.; Mazzocchi, F.; Cossio, F.; Cecchini, M.; Bedini, R.; Monarca, D. Comparisons between Battery Chainsaws and Internal Combustion Engine Chainsaws: Performance and Safety. *Contemp. Eng. Sci.* **2016**, *9*, 1315–1337. [CrossRef]
42. Kiehne, H.A. *Battery Technology Handbook*, 2nd ed.; CRC Press: New York, NY, USA, 2003; Volume 118, ISBN 0203911857.
43. Hanisch, C.; Loellhoeffel, T.; Diekmann, J.; Markley, K.J.; Haselrieder, W.; Kwade, A. Recycling of Lithium-Ion Batteries: A Novel Method to Separate Coating and Foil of Electrodes. *J. Clean. Prod.* **2015**, *108*, 301–311. [CrossRef]
44. Boubaker, K.; Colantoni, A.; Allegrini, E.; Longo, L.; Di Giacinto, S.; Monarca, D.; Cecchini, M. A Model for Musculoskeletal Disorder-Related Fatigue in Upper Limb Manipulation during Industrial Vegetables Sorting. *Int. J. Ind. Ergon.* **2014**, *44*, 601–605. [CrossRef]
45. Neri, F.; Laschi, A.; Frassinelli, N.; Fabiano, F.; Foderi, C.; Marchi, E.; Marra, E. Battery- and Petrol-Powered Chainsaws: An Investigation of Productivity in Conifer Thinning. *Forests* **2023**, *14*, 183. [CrossRef]
46. Pandur, Z.; Šušnjar, M.; Bačić, M. Battery Technology—Use in Forestry. *Croat. J. For. Eng.* **2021**, *42*, 135–148. [CrossRef]
47. *UNI EN ISO 5349-1:2004*; Mechanical Vibration—Measurement and Evaluation of Human Exposure to Hand- Transmitted Vibration—Part 1: General Requirements. International Organization for Standardization: Geneva, Switzerland, 2004.
48. *UNI EN ISO 5349-2:2015*; Mechanical Vibration—Measurement and Evaluation of Human Exposure to Hand- Transmitted Vibration—Part 2: Practical; Guidance for Measurement at the Workplace. International Organization for Standardization: Geneva, Switzerland, 2015.
49. *ISO 13061-2:2014*; Physical and Mechanical Properties of Wood—Test Methods for Small Clear Wood Specimens—Part 2: Determination of Density for Physical and Mechanical Tests. International Organization for Standarization: Geneva, Switzerland, 2014.
50. Sakakibara, H.; Kondo, T.; Koike, Y.; Miyao, M.; Furuta, M.; Yamada, S.; Sakurai, N.; Ono, Y. Combined Effects of Vibration and Noise on Palmar Sweating in Healthy Subjects. *Eur. J. Appl. Physiol. Occup. Physiol.* **1989**, *59*, 195–198. [CrossRef]
51. Sisto, R.; Botti, T.; Cerini, L.; Di Giovanni, R.; Marchetti, E.; Lunghi, A.; Sacco, F.; Sanjust, F.; Tirabasso, A.; Moleti, A. Synergistic Effects of Noise and Hand-Arm Vibration on Distortion Product Otoacoustic Emissions in Healthy Subjects. *Int. J. Ind. Ergon.* **2017**, *62*, 48–54. [CrossRef]
52. European Commission Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (Noise). *Off. J. Eur. Communities* **2003**.
53. *ISO 9612:2011*; Acoustics—Determination of Occupational Noise Exposure—Engineering Method. 2011. International Organization for Standardization: Geneva, Switzerland, 2011.
54. *ISO 11201:2010*; Acoustics: Noise Emitted by Machinery and Equipment; Determination of Emission Sound Pressure Levels at a Work Station and at Other Specified Positions in an Essentially Free Field over a Reflecting Plane with Negligible Environmental Corrections. International Organization for Standarization (ISO): Geneva, Switzerland, 2010.
55. R Core Team. *R: A Language and Environment for Statistical Computing*; The R Foundation for Statistical Computing: Vienna, Austria, 2020; Volume 1.
56. Konietschke, F.; Placzek, M.; Schaarschmidt, F.; Hothorn, L.A. Nparcomp: An R Software Package for Nonparametric Multiple Comparisons and Simultaneous Confidence Intervals. *J. Stat. Softw.* **2015**, *64*, 1–17. [CrossRef]
57. Rottensteiner, C.; Stampfer, K. Evaluation of Operator Vibration Exposure to Chainsaws Equipped with a Kesper Safety Bar. *Scand. J. For. Res.* **2013**, *28*, 193–200. [CrossRef]
58. Pitts, P. *Hand-Arm Vibration Emission of Chainsaws-Comparison with Vibration Exposure*; Health and Safety Laboratory: Buxton, UK, 2004.

59. Takimoto, Y.; Bottoms, D.J.; Stayner, R.M. The Vibration Characteristics of a Chainsaw Fitted with a Two Cylinder Engine. In *Noise and Vibration in Agriculture and Forestry, Proceedings of the 8th Joint Ergonomics Symposium, Silsoe, UK, 9–12 September 1985*; EurekaMag: Dallas, TX, USA, 1985.
60. Rukat, W.; Jakubek, B. The Influence of the Cutting Tooth Design and Wear of a Saw Chain on the Vibration Level of a Chainsaw. *Vib. Phys. Syst.* **2017**, *28*, 1–8.
61. Laschi, A.; Neri, F.; Marra, E.; Fabiano, F.; Frassinelli, N.; Marchi, E.; Paoloni, R.; Foderi, C. Comparing the Productivity of the Latest Models of Li-Ion Battery and Petrol Chainsaws in a Conifer Clear-Cut Site. *Forests* **2023**, *14*, 585. [CrossRef]