PHILIPPINE ENGINEERING JOURNAL
PEJ 2025; Vol. 46, No. 1: 143-161

Received: 17 February 2025
Received in Revised Form: 19 April 2025
Accepted: 12 June 2025

Investigating the Prevalence of Symptoms of Vibration-Related Illnesses Among Agricultural Machine Operators

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Abstract *– The study assessed the prevalence of vibration-related symptoms and illnesses among agricultural machine operators, specifically length of years prior to the onset of symptoms of whole-body musculoskeletal disorder (MSD), probable existence of hand-arm vibration syndrome, and prevalence of carpal tunnel syndrome. It tested the correlation between various demographic characteristics of the operators and the occurrence and severity of the symptoms. One hundred operators from Tarlac and Laguna, Philippines, were invited to participate. The mean (± SD) age and farm-related experience are 44.92 ± 14.78 years old and 11.90 ± 10.17 years, respectively. Three questionnaires were used: the Extended Nordic Musculoskeletal Disorder (NMQ-E), the Cold Intolerance Symptom Severity, and the Boston Carpal Tunnel Syndrome Questionnaire. Data were gathered through group interviews and focus group discussions. Correlation analyses were performed to determine the influence of demographic variables to the occurrence and severity of symptoms. It was found that whole-body MSD symptoms are present in all covered body parts in the NMQ-E, with a maximum prevalence of 38% in the lower back and minimum prevalence of 12% in the elbows. The earliest average onset of MSD symptoms was observed in the shoulders after a mean of 9.0 operating years. The study also revealed that operators have experienced negative impacts on the hands and wrists, which manifested in the occurrence of diminished hand functions. Finally, statistical evaluations showed significantly moderate correlations between: (1) CTS symptoms with the number of hours operating a tractor in a week and number of years operating a tractor; (2) HAVS symptoms with the number of hours operating a tractor in a week, number of years operating a tractor, and the time of the day the equipment is being used. Hence, long-term and constant vibration exposure can potentially lead to the onset of MSD and significantly affect fundamental hand functions.*

Keywords*: vibration-related illnesses, MSD, HAVS, CTS, long-term effects of vibration*

I. INTRODUCTION

The Philippines is an archipelagic country that uses 41.72% of its total land area for agriculture [1]. The country's soil is highly suitable for rice cultivation, trees, and crops. In effect, the Philippine Statistics Authority recorded that agriculture provided 24.5% of employment in June 2022 [2] and recorded a contribution of 8.50% of gross domestic product (GDP) to the country's total [3]. With these remarks, agriculture plays a vital role in the country's economy and employment.

With the world experiencing industrialization through modernizing different industries, the agriculture sector is not exempt from using machines and equipment leading to more efficient farming where more tasks and areas are accomplished at the right time [4, 5]. In this

regard, farm mechanization in the Philippines grew from 1.23 horsepower per hectare (hp/ha) in 2011 to 2.679 hp/ha in 2023 [6, 7], suggesting the increase in the number of machines being used in the country. As a result, this prompted an increase in the number of agricultural machine operators. In fact, as of 2012, there are a total of 5.5 million agricultural operators in the country [8].

The improvement in mechanization also brought better efficiency and profitability to farming [22]. However, it should be noted that machines produce vibration transmitted through the body in the form of whole-body vibration (WBV) or through hand-transmitted vibration (HTV). Exposure to these vibrations may cause trauma and changes to muscles, bones, joints, and tendons, damage to body organs, and impairment to the nervous system in the fingers, hands, and arms as well as physiological tissues and blood vessels [9,10]. Further, these vibrations at specific frequencies and directions may cause pain or discomfort to operators [11,12]. These damages may accumulate and result in the development of occupational diseases and disorders such as musculoskeletal disorders (MSD), cardiovascular diseases, gastrointestinal problems, and certain cancers that affect workers' performance [13, 14, 15]. Specifically, operators exposed to rock drillers, heavy trucks, earth moving equipment, and powered-hand tools may experience work-related MSD, or simply MSD in the head, neck, back, spine, arms, hand, and hips, and vibration-induced white finger, also called hand-arm vibration syndrome (HAVS) [16, 17, 18, 19].

Studies have shown that agricultural operators in the Philippines are exposed to vibrations larger than the exposure limit value (ELV) and exposure action value (EAV) set by the ISO Standards [5, 15, 20]. For instance, a study conducted on the HTV from an ergonomically designed two-wheel tractor, revealed that operators were exposed to average vibration frequencies ranging between 10.50 - 17.02 m/s^2 [21]. As per the standards, the EAV must be 2.5 m/s^2 while the ELV must not exceed 5 m/s^2 at a daily exposure of 8 hours. In another study, data showed that daily WBV levels in plowing, harrowing, and rotavating exceeded the EAV [23]. Based on these recorded vibration values, operators may be at risk to experience vibration-induced white fingers, shoulder discomfort, and lower handgrip strength [24].

Despite the existence of studies identifying the discomfort and vibration frequencies experienced by Filipino agricultural operators, there are still limited studies that identify the possible vibration-related illnesses and symptoms experienced by agricultural machine operators in the Philippines. A systematic literature review of publications related to prevalence of MSDs in the agricultural sector from 1995 to 2020 showed that studies were mainly focused on developed countries with more advanced technology than the Philippines. Noteworthy findings of the review include (1) frequent neck-related MSDs among dairy farmers in Malaysia, Thailand, USA and Canada, (2) limited exploration of hip-related MSDs in developing countries though studies in developed countries like South Korea and the USA, suggest a relationship of hip MSD with long time of driving tractors, and (3) prevalence of MSDs among livestock farmers in Greece, USA, South Korea, Sweden, Germany, Poland, and Canada [24]. Given the differences in the technology and ecological topology of the Philippines, as well as the working conditions and physical profile of agricultural workers relative to other countries, understanding how agricultural machine operators are impacted will enable interventions that promote welfare of the agricultural workers towards sustainability.

The importance of agriculture in the Philippines and the paucity of literature investigating how agricultural workers are impacted by vibration-inducing equipment, particularly MSD, thus merits investigation.

The study aimed to assess the prevalence of vibration-related symptoms and illnesses among agricultural machine operators. Specifically, the study aimed to (1) describe the onset of symptoms of whole-body MSD and HAVS being experienced by the operators; (2) identify the occurrence and severity of existing vibration-related illnesses of the operators; (3) determine the correlation between various demographic variables and the occurrence and severity of musculoskeletal disorders, carpal tunnel syndrome, and HAVS symptoms, or generally vibration-related illnesses; and (4) propose corrective actions that can reduce the effects of vibrations from agricultural machines based on related studies.

II. METHODOLOGY

A. Participants

Farmers from Tarlac and Laguna were chosen as respondents. Due to budget and time constraints, as well as logistical limitations, only 100 agricultural farm operators were recruited. Seventy five percent (75%) of the respondents were farmers-members of the cooperative reached through the assistance of the RiceBiz Program of the Philippine Rice Research Institute (PhilRice) in Nueva Ecija, while 25% came from Laguna. All participants were male, with a mean age (± SD) of 44.92 ± 14.78 years old.

B. Materials

The study used a printed survey form consisting of a collection of questions and standardized questionnaires aimed at eliciting the participants' demographics, experience, and symptoms of vibration-related illnesses. The questions were translated into Tagalog to make it easier for the participants to comprehend the questions.

Pre-screening, primarily considering previous and existing injuries, was included in the demographics part of the questionnaire. The participants were asked about the other diseases they are currently experiencing including the cases of hypertension or high blood pressure, arthritis, heart disease, asthma, diabetes, kidney stone, coughing, and stomachache. These were considered in asking relevant questions to the participants and identifying participants whose data may be excluded during the analysis.

The three sets of standardized questionnaires include the Extended Nordic Musculoskeletal Questionnaire (NMQ-E), Cold Intolerance Symptom Severity (CISS) Questionnaire, and Boston Carpal Tunnel Syndrome Questionnaire (BCTQ). These questionnaires were selected considering Cronbach's alpha values to make sure that they are all credible and reliable. Primarily, these were used to assess the effects of continuous and constant exposure to agricultural machinery to the whole-body and hand-arm area of the operators.

The NMQ-E Questionnaire, with a Cronbach's alpha of 0.945, was used to study the prevalence of symptoms of musculoskeletal disorders that arise in an ergonomic or

occupational health context [25,26]. In the study, it was used to identify the onset and the existence of whole-body MSD symptoms from the exposure to agricultural machinery. The second set is the CISS Questionnaire with a Cronbach's alpha of 0.922, which was used to identify HAVS symptoms [27]. It was used to measure the severity of cold intolerance in relation to the identification of the existence of HAVS. This set of questions showed high agreement with the Stockholm Workshop Scale, which is a subjective history-based approach to grade the severity of HAVS [28,29]. The last set of questions is the BCTQ, which has a Cronbach's alpha of 0.860. This was used to identify symptoms of carpal tunnel syndrome (CTS), such as physiological symptoms experienced in the hands and wrists and identify the effects of vibration to fundamental hand functions [29]. The prevalence of CTS symptoms was identified through the Functional Status Scale which evaluated the level of hand function, and the Symptom Severity Scale which evaluated the severity of symptoms [30]. These questionnaires were used to assess the effects of continuous and constant exposure to agricultural machinery to the whole-body and hand-arm area of the operators.

The translated questionnaires were tested for validity using ten sample points via ANOVA two-factor without replication. The validation results presented in Table 1 showed acceptable Cronbach's alpha values (i.e., > 0.70). Appendix 4A presents the questionnaires as used in the study.

Table 1. Reliability Results of Translated Questionnaires

Questionnaires Used	Cronbach's Alpha
Boston Carpal Tunnel Syndrome	0.91
Cold Intolerance Symptom Severity	0.98
Severity	0.96
Frequency	0.89
Duration	0.94
Coping	0.90
Effect	0.96
Nordic Musculoskeletal Questionnaire-Extended	0.94

C. Process of Data Collection

The study's purpose and data gathering methodology were explained to the participants, followed by the signing of the consent form. The survey was facilitated through the distribution of printed sets of questionnaires. The participants were instructed to answer the survey on their own. Four researchers distributed and collected the forms but also provided assistance to some respondents (n < 10) who had difficulty reading the questions (e.g., because

the font size is small, they have poor eyesight, etc.) or writing on the paper (e.g., because their writing hand is shaking, they had difficulty in gripping the pen, etc.). Assistance provided was either through reading directly from the questionnaire or writing precisely what the participants stated.

D. Data Processing and Analysis

1. Consolidation and Data Screening

The responses collected from the printed questionnaires were inputted, sorted, and analyzed in MS Excel. Specifically, descriptive statistical analyses such as mean and standard deviation were used for the demographics, experiences, MSD symptoms, physiological symptoms experienced in the hands and wrists, and the effects of vibration to the hand functions. Aside from these, the collected data was also used for the determining correlation between demographic variables and symptoms of vibration-related illnesses (refer to Appendix 4B and Appendix 4C for the Variables Used and Summary of Statistical Test Results).

Among the 100 participants, nine had existing injuries on various body parts, including fractures and consistent pains. Consequently, seven participants were excluded from the NMQ-E assessment, two were excluded from the CISS assessment, and one was excluded from the BCTQ evaluation. Essentially, the inclusion and exclusion segment were deemed important because they eliminated the possibility that the experienced pain in the mentioned body part is not an effect of exposure to vibration, but instead, because of the injury.

2. Assessment of Prevalence and Onset of Symptoms

Following the screening process, invalid responses were excluded from analysis. These include 1) responses from participants with existing injury in the specified body part and/or 2) inconsistent responses to other questions across the body part (e.g., stated that he had pain but did not specify how frequent the pain was felt). Prevalence was computed as the percentage of respondents who experienced MSD symptoms divided by the number of valid responses.

Meanwhile, the onset of pain or discomfort along the body parts indicated in the NMQ-E was estimated using Eq. (1). The mean onset for a certain body part was obtained only for those who experienced pain or discomfort on the specified body part.

$$Onset_{MSD(i)} = years\ of\ operating - years\ of\ experiencing\ pain\ along\ i \qquad Eq.\ (1)$$

Where: years of operating is the number of years using agricultural machinery and *i* is the body part in consideration (e.g., neck, shoulder, etc.)

3. Categorization of Responses for Severity

To simplify the analysis, questions were grouped to describe the degree of severity of symptoms. For instance, for the NMQ-E set, the severity of MSD symptoms was described as mild, moderate, and severe depending on the frequency and consistency. A mild severity was recorded if the operators experienced pain or discomfort on a certain body part only during the day of the interview or at any time during the last month. Generally, mild was used to describe the early stage or onset of MSD symptoms. A moderate severity was identified when the pain or discomfort was experienced during the last 12 months and it had prevented the operators from performing certain activities. Moderate was used to describe the recurring or prolonged

presence of MSD symptoms. Finally, a severe case was set if the operators had been hospitalized because of the pain or discomfort or they had been forced to change jobs. Severe was used to describe the seriousness of effects of MSD that already affected the participant's way of living. Table 2 presents how the questions from the NMQ-E were grouped based on the aforementioned categorization.

Table 2. Categorization of severity of whole-body MSD symptoms based on the questions from the NMQ-E.

Evaluated Severity	NMQ-E-Based Questions
Mild	Have you had trouble (ache, pain, discomfort) today?
	Have you had trouble (ache, pain, discomfort) at any time during the last month (4 weeks)?
Moderate	Have you had trouble (ache, pain, discomfort) at any time during the last 12 months?
	During the last 12 months: have you been prevented from doing your normal work (at home or away from home) because of the trouble?
	During the last 12 months: have you seen a doctor, physiotherapist, chiropractor or other such person because of the trouble?
	During the last 12 months: have you taken medication because of the trouble?
	During the last 12 months: have you taken sick leave from work/ studies because of the trouble?
Severe	Have you ever been hospitalized because of the trouble?
	Have you ever had to change jobs or duties (even temporarily) because of the trouble?

Meanwhile, the scores from the CISS Questionnaire were computed and the level of severity was identified following the categorization from related literature. Table 3 summarizes that categorization in terms of the CISS score.

Table 3. Categorization of cold intolerance status according to the CISS Score.

Categorization of Cold Intolerance	CISS Score
Healthy	0-14
Mild cold intolerance	15-24
Moderate cold intolerance	25-34
Severe cold intolerance	35-42
Very severe cold intolerance	43-46

4. Investigation of Factors Affecting the Prevalence of Illnesses

Correlation analysis was conducted to investigate which demographic factors affect the prevalence of MSD symptoms, decline on hand functionalities, and HAVS symptoms. All variables were tested for independence (see Appendix 4C for the results of the Test for Independence), followed by the appropriate correlation analysis technique based on the variable properties. Cramer's V was used for categorical variables while Phi Coefficient was used for binary variables. The summary of the tests conducted for each dependent and independent variable is shown in Table 4. Each independent variable and dependent variable is paired and tested for independence and correlation iteratively.

Table 4. Summary of statistical tests conducted between demographic variables, body parts, BCTQ, and CISS.

Demographics to Body Parts			
Independent Variables	Dependent Variables	Test for Independence	Correlation Test
Age, Highest Educ Attainment, Previous Job, Concurrent Job, Sleep, Illness, Vices, Injury, Experience 2-Wheel, Experience 4-Wheel, Weekly Tool Use, Time of day	Neck, Shoulder, Upper back, Elbows, Lower back, Wrists or hands, Hips or thighs, Knees, Ankles or feet	Chi-Square, Likelihood Ratio, Fisher's Exact Test	Cramer's V or Phi Coefficient

Demographics to Boston Carpal Tunnel Syndrome Questionnaire			
Independent Variables	Dependent Variables	Test for Independence	With correlation? Test for the strength of association
Age, Highest Educ Attainment, Previous Job, Concurrent Job, Sleep, Illness, Vices, Injury, Experience 2-Wheel, Experience 4-Wheel, Weekly Tool Use, Time of day	Functional Status Scale (Writing, Buttoning, Book, Telephone, Jar, House Chores, Grocery Basket, Bathing Or Dressing) and Symptom Severity Scale (Pain Night, Frequency pain night, Morning pain, Frequency pain morning, Duration pain morning, Numbness, Weakness, Tingles, Severity W/T Night, Frequency N/T Night, Small items)	Chi-Square, Likelihood Ratio, Fisher's Exact Test	Cramer's V or Phi Coefficient
Demographics to Cold Intolerance Symptom Severity			
Independent Variables	Dependent Variables	Test for Independence	With correlation? Test for the strength of association
Age, Highest Educ Attainment, Previous Job, Concurrent Job, Sleep, Illness, Vices, Injury, Experience 2-Wheel, Experience 4-Wheel, Weekly Tool Use, Time of day	Severity, Frequency, Duration Before, Coping (Pain, Numbness, Stiffness, Weakness, Aching, Swelling, Skin color change), Effect (Holding items, Washing, Wind after hot bath, Season, House Chores, Interests, Un/Dressing, Tying shoes, Work)	Chi-Square, Likelihood Ratio, Fisher's Exact Test	Cramer's V or Phi Coefficient

III. RESULTS AND DISCUSSION

A. Demographics and Experience of the Participants

Survey results showed that the common machines being used are 2-wheel tractors and 4-wheel tractors, wherein 88% operate the former and 44% operate the latter. Meanwhile, about 4% use a harvester, and 2% are familiar with irrigation, thresher, and transplanter. Also, 39% operate more than one of the following machineries. In addition, respondents had been operating agricultural machines for 11.90 ± 10.17 years, averaging 26.23 ± 14.02 hours per week.

With respect to lifestyle, 69% occasionally drink liquor and 56% are tobacco smokers or have a history of smoking tobacco. Aside from that, 66% actively engaged in other activities including sports like basketball, volleyball, cycling, billiards, and table tennis, as well as weightlifting, walking, and running, tending to plants, cooking, and raising pigs, and 25% have other work aside from operating machines. About 30% suffer from certain diseases including hypertension or high blood pressure, arthritis, heart disease, asthma, diabetes, kidney stones, coughing, and stomach ache.

B. Assessment of Whole-Body MSD Symptoms using the NMQ-E

1. Prevalence of whole-body MSD symptoms

As depicted in Table 5, among the valid responses, pain was experienced most prevalently in the lower back (38%), shoulder (35%), hip (32%) and back (32%). These results indicate that the working posture might have contributed to the upper body symptoms as these body parts exert the most force during the use of tractors. Moreover, the upper body symptoms might have been intensified by the vibration transferred through the upper body.

Table 5. Actual count of affected and unaffected participants (N = 100).

Body part	Experienced pain / discomfort (n | %)	Did not experience pain / discomfort (n | %)	Excluded because of existing injuries / invalid input in the survey (N – n)
Neck (n = 99)	29 | 29.3%	70 | 70.7%	1
Shoulder (n = 96)	34 | 35.4%	62 | 64.6%	4
Upper back (n = 99)	32 | 32.3%	67 | 67.7%	1
Elbow (n = 99)	12 | 12.1%	87 | 87.8%	1
Lower back (n = 96)	36 | 37.5%	60 | 62.5%	4
Hand and wrist (n = 99)	24 | 24.2%	75 | 75.8%	1
Hips (n = 98)	31 | 31.6%	67 | 68.4%	2
Knee (n = 99)	19 | 19.2%	80 | 80.8%	1
Foot and ankle (n = 96)	20 | 20.8%	76 | 79.2%	4

2. Onset of whole-body MSD symptoms

Figure 1 shows the estimated onset of pain in the different body parts based from the NMQ-E. The results indicate that the earliest onset of pain and/or discomfort was first experienced on the shoulders (after 9 years) and the knees (after 9.5 years) which might be primarily contributed by the pressure to direct the movement of the tractors. It was then followed by the pain and/or discomfort on the hands and wrists (after 10.3 years) which are directly exposed to the vibration from agricultural machinery.

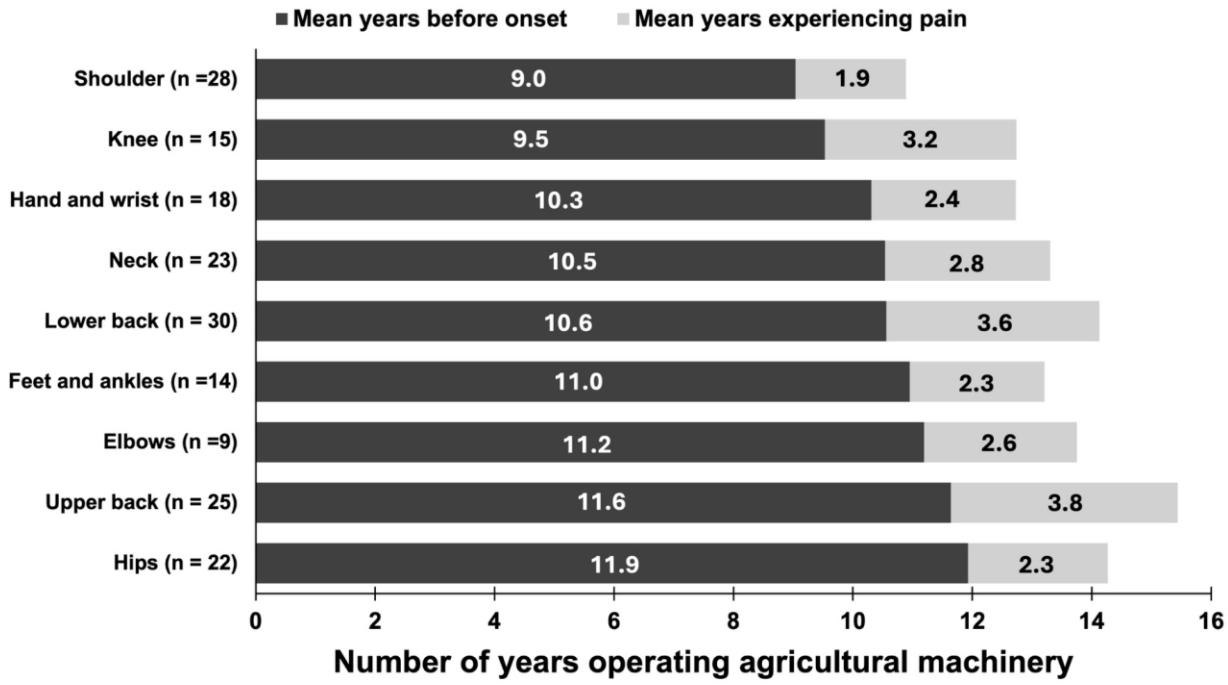

Figure 1. Computed mean years before onset of experiencing whole-body MSD symptoms (N = 100).

3. MSD symptom severity

Table 6 presents the summarized severity levels of MSD symptoms along the various body parts. Across all body parts, the moderate level of severity was reported by a majority of the respondents. Consistent with the results of the onset analysis, the shoulders had the highest response rate under the moderate severity level. From the NMQ-E data, this implies that most operators had experienced pain or discomfort within the last 12 months or moderate severity (refer to Table 2) in various body parts. For instance, 42% experienced moderate pain in the hips (n = 31, from Table 5) and 86% had moderate pain in the shoulder (n = 34, from Table 5). Simply, moderate severity implies that they had been affected by the said pain either in terms of discomfort in performing daily activities, having to take medications to relieve the pain, having to go to a doctor, or needing to skip work. Meanwhile, almost half of the participants reported having experienced mild pains on the hip area (42%). Finally, severe cases were reported to be primarily experienced on the feet and ankles (20%).

Table 6. Percentage of operators classified according to the severity of reported whole-body MSD symptoms (N = 100).

Severity	Body Part								
	Neck (n = 29)	Shoulder (n = 34)	Upper back (n = 32)	Elbow (n = 12)	Lower back (n = 36)	Hand and Wrist (n = 24)	Hips (n = 31)	Knee (n = 19)	Feet and Ankle (n = 20)
Mild	7 | 24%	5 | 14%	5 | 15%	3 | 25%	7 | 19%	9 | 38%	13 | 42%	5 | 26%	5 | 25%
Moderate	18 | 62%	29 | 86%	22 | 69%	8 | 67%	24 | 67%	13 | 54%	13 | 42%	12 | 63%	11 | 55%
Severe	4 | 14%	0 | 0%	5 | 16%	1 | 8%	5 | 14%	2 | 8%	5 | 16%	2 | 11%	4 | 20%

C. Severity of HAVS based on the computed CISS scores

In the study, the probable existence of HAVS due to long-term exposure to machinery vibration was based on the CISS test scores (shown earlier in Table 3). Several studies correlated the CISS scores with HAVS. Among the included operators, 85 had no cold intolerance symptoms, implying a generally healthy state in terms of HAVS. On the other hand, 12 had mild severity and 1 reported a severe case.

D. Effects on fundamental hand functions in terms of CTS symptoms

Among the participants (N = 100, n = 99), more than half reported discomfort and numbness irrespective of the time of day (refer to Table 7 header). Additionally, the severity of the existing symptoms (Table 7) indicates that among the participants who experienced hand and wrist discomfort, numbness, weakness, and tingling, around 60% to 80% were under the mild severity while 20% to 35% (or 10 to 17 of the affected participants) were under the moderate rating. This is not far from the number of participants who reported moderate hand and wrist pain (about 13 or 54% of the 24 affected participants) in the NMQ-E test. Meanwhile, a moderate severity (57% of those who were affected) on the weakening of manipulative dexterity was seen.

Table 7. Percentage of operators classified based on the symptom severity scale (N = 100).

Severity	Carpal Tunnel Syndrome (CTS) Symptoms Severity Scale						
	Discomfort during the day (n = 54)	Discomfort at night (n = 57)	Numbness during the day (n = 55)	Numbness at night (n = 54)	Weakness (n =48)	Tingling (n = 60)	Weakened Manipulative Dexterity (n = 23)
Mild	42 | 78%	41 | 72%	41 | 75%	35 | 65%	30 | 63%	44 | 74%	9 | 39%
Moderate	11 | 20%	15 | 26%	13 | 24%	14 | 26%	17 | 35%	14 | 23%	13 | 57%
Severe	1 | 2%	1 | 2%	1 | 2%	5 | 9%	1 | 2%	2 | 3%	0 | 0%
Very Severe	0 | 0%	0 | 0%	0 | 0%	0 | 0%	0 | 0%	0 | 0%	1 | 4%

The second part of the BCTQ evaluated the functional status scale. Basically, this section identified the potential contribution of vibration to the various fundamental hand functions. Table 8 presents the perceived difficulty of carrying out daily tasks which may be associated with the experienced vibration from tractors. In general, majority of the participants experienced mild difficulty executing the different tasks (50-70%), except for writing (45%).

This suggests minimal difficulty and interference in performing daily tasks. Still, a significant proportion (20-50%) indicated moderate severity suggesting completion of the task with limitations associated with the symptoms of CTS. Notably, 11 % reported very severe difficulty buttoning of clothes which implies reduced fine motor skills.

Table 8. Percentage of operators experiencing difficulty on various daily life activities based on the functional status scale (N = 100).

Severity	Carpal Tunnel Syndrome (CTS) Functional State Status							
	Writing (n = 22)	**Buttoning of clothes (n = 18)**	**Holding a book while reading (n = 25)**	**Gripping of a telephone handle (n = 10)**	**Opening of a jar (n = 24)**	**Household chores (n = 32)**	**Carrying of a grocery basket (n = 36)**	**Bathing or dressing (n = 13)**
Mild	10 | 45%	9 | 50%	17 | 68%	7 | 70%	14 | 58%	17 | 53%	18 | 50%	8 | 62%
Moderate	11 | 50%	7 | 39%	6 | 24%	2 | 20%	9 | 38%	13 | 41%	14 | 39%	5 | 38%
Severe	1 | 5%	0 | 0%	2 | 8%	1 | 10%	1 | 4%	2 | 6%	3 | 8%	0 | 0%
Very Severe	0 | 0%	2 | 11%	0 | 0%	0 | 0%	0 | 0%	0 | 0%	1 | 3%	0 | 0%

E. Correlation Analyses

Correlations and strength of correlations between demographics and symptoms were determined. It was found that moderate correlations exist between some demographic information and CTS symptoms, HAVS symptoms, and MSD symptoms. Tables 9 and 10 present detailed information of moderately correlated variables. All test results are presented in Appendix 4C. It can be seen in Table 9 that the weekly tool use or the number of hours operating the equipment in a weekly basis has three significantly moderate correlations with carpal tunnel syndrome symptoms, which indicate that this can become a good predictor of carpal tunnel syndrome prevalence and severity.

Table 9. Demographic information and CTS symptoms with level of correlations (n is the number of affected operators, r is the level of correlations, and ***p** denotes significant correlations and with significant test for independence).

Demographics	Functional Status Scale	Symptom Severity Scale			
	Buttoning of clothes	**Frequency of night pains**	**Tingling**	**Severity of weakness or tingles**	**Frequency of numbness or tingles**
number of years operating a 2-wheel tractor	***n = 87*** ***r = 0.312*** ****p = 0.031***	n = 86 r = 0.212 p = 0.493	n = 87 r = 0.210 p = 0.448	n = 87 r = 0.167 p = 0.838	n = 86 r = 0.227 p = 0.344
number of years operating a 4-wheel tractor	n = 43 r = 0.333 p = 0.300	n = 43 r = 0.302 p = 0.466	n = 43 r = 0.249 p = 0.723	n = 43 r = 0.350 p = 0.230	n = 43 r = 0.375 p = 0.111
number of hours operating the equipment	n = 100 r = 0.284 p = 0.143	***n = 100*** ***r = 0.294*** ****p = 0.075***	***n = 100*** ***r = 0.327*** ****p = 0.020***	***n = 100*** ***r = 0.300*** ****p = 0.075***	n = 100 r = 0.232 p = 0.580
time of day operating the equipment	***n = 100*** ***r = 0.329*** ****p = 0.012***	***n = 100*** ***r = 0.453*** ****p < 0.001***	***n = 100*** ***r = 0.309*** ****p = 0.021***	***n = 100*** ***r = 0.296*** ****p = 0.030***	***n = 100*** ***r = 0.261*** ****p = 0.077***

Similar with Table 9, Tables 10a and 10b show that the number of years operating the tractor, number of hours operating them, and the time of the day they are being operated have significantly moderate correlations with the prevalence and severity of hand-arm vibration syndrome symptoms, which imply that they can be good predictors of such illness.

Table 10a. Demographic information and HAVS symptoms with level of correlations (n is the number of affected operators, r is the level of correlations, and ***p** denotes significant correlations and with significant test for independence).

Demographics	Severity	Frequency		
	Numbness severity	Pain frequency	Aching frequency	Skin color change frequency
number of years operating a 2-wheel tractor	n = 87 r = 0.255 p = 0.124	***n = 85*** ***r = 0.318*** ****p = 0.012***	***n = 84*** ***r = 0.290*** ****p = 0.049***	n = 84 r = 0.215 p = 0.453
number of years operating a 4-wheel tractor	***n = 43*** ***r = 0.400*** ****p = 0.088***	n = 42 r = 0.332 p = 0.320	***n = 41*** ***r = 0.439*** ****p = 0.022***	n = 41 r = 0.266 p = 0.669
number of hours operating the equipment	n = 100 r = 0.281 p = 0.129	n = 99 r = 0.213 p = 0.766	n = 98 r = 0.240 p = 0.531	n = 98 r = 0.295 p = 0.147
time of day operating the equipment	n = 100 r = 0.267 p = 0.122	n = 100 r = 0.180 p = 0.357	***n = 99*** ***r = 0.329*** ****p = 0.013***	***n = 99*** ***r = 0.449*** ****p < 0.001***

Table 10b. Demographic information and HAVS symptoms with level of correlations (n is the number of affected operators, r is the level of correlations, and ***p** denotes significant correlations and with significant test for independence).

Demographics	Duration			Coping	Effects on Common Tasks		
	Pain duration	Stiffness duration	Aching duration	Pain coping	Pain when holding items	Pain after bath	Pain when doing daily task
number of years operating a 2-wheel tractor	***n = 85*** ***r = 0.292*** ****p = 0.069***	***n = 83*** ***r = 0.346*** ****p = 0.011***	***n = 85*** ***r = 0.476*** ****p < 0.001***	***n = 86*** ***r = 0.322*** ****p = 0.008***	n = 87 r = 0.209 p = 0.491	***n = 87*** ***r = 0.294*** ****p = 0.032***	n = 87 r = 0.228 p = 0.322
number of years operating a 4-wheel tractor	n = 41 r = 0.314 p = 0.426	n = 39 r = 0.327 p = 0.399	n = 39 r = 0.312 p = 0.474	n = 41 r = 0.466 p = 0.023	n = 43 r = 0.252 p = 0.708	n = 43 r = 0.388 p = 0.114	***n = 43*** ***r = 0.425*** ****p = 0.049***
number of hours operating the equipment	***n = 98*** ***r = 0.355*** ****p = 0.017***	n = 96 r = 0.267 p = 0.319	***n = 96*** ***r = 0.332*** ****p = 0.048***	n = 99 r = 0.263 p = 0.300	***n = 100*** ***r = 0.372*** ****p = 0.001***	n = 100 r = 0.247 p = 0.429	n = 100 r = 0.270 p = 0.202
time of day operating the equipment	***n = 99*** ***r = 0.268*** ****p = 0.029***	n = 97 r = 0.148 p = 0.345	***n = 97*** ***r = 0.317*** ****p = 0.008***	n = 100 r = 0.179 p = 0.361	n = 100 r = 0.235 p = 0.130	n = 100 r = 0.229 p = 0.148	n = 100 r = 0.276 p = 0.100

Meanwhile, significant correlations were also seen between demographics and musculoskeletal disorder symptoms specifically: (1) age and shoulder (r = 0.337; p = 0.022) and wrists or hand pain (r = 0.321; p = 0.034), (2) having vices and upper back pain (r = 0.305; p = 0.002), (3) educational attainment and neck pain (r = 0.297; p = 0.035), (4) number of years operating a 2-wheel tractor and upper (r = 0.375; p = 0.016) and lower back pain (r = 0.405; p = 0.007), and (5) weekly tool use and wrists or hand pain (r = 0.364; p = 0.038). These can

also mean that age, number of years of operating a tractor, having vices, highest educational attainment, and the number of hours the operators use the tractors are significantly associated with certain MSD symptoms. These associations may indicate potential risk factors worth exploring further through predictive or causal analyses.

Discussion

The prevalence of vibration-related illnesses such as whole-body MSD, existence of HAVS through the CISS scores, and presence of CTS through the BCTQ data are evident in this study. Specifically, the symptoms are present and prominent after a long-term, constant, and continuous exposure to vibration from agricultural machinery (as depicted in Figure 1), such as the 2-wheel and 4-wheel tractor.

A. Prevalence of MSD Symptoms and their Correlation with Demographic Variables

Symptoms of MSD are reported on all body parts stipulated in the NMQ-E. The upper body and mid-section including the neck, shoulder, upper and lower back, and hips have the higher prevalence ranging from 29% to 36% while the lower body parts seem to be less affected with prevalence less than 25%. This implies that the upper limb area is most strained when operating agricultural machinery. Similar to other hand-held machinery such as chainsaws and jackhammers, a hand tractor is operated using the upper limb mainly for pushing, lifting, and maneuvering along the paddy farm field. Related study found that handheld machines are greatly associated to pains in upper extremities primarily because of whole body vibration and hand-arm transmitted vibration [31]. Hence, these are the body parts that evidently showed muscle pains and discomfort (Figure 2).

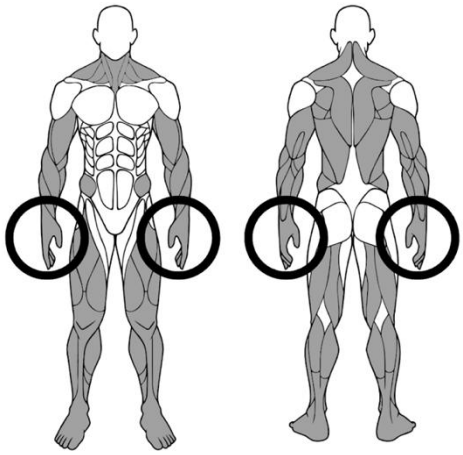

Figure 2. Muscles used when operating tractors (highlighted) and body part exposed to vibration (encircled)

However, unlike other hand-held tools or equipment, the onset of MSD symptoms in farm machinery operators seemed to be longer or farther along the period of exposure. In this study, it was determined that the mean years before onset of symptoms along the shoulder is 9.04 years while for the hands and wrists, it is about 10.31 years. Similarly, more than 10 years of exposure is needed before a possible onset of symptoms along the other upper body parts, such as the back and the neck, can be observed. This is possibly because of the level of exertion tractor handlebars or steering wheels are being held or gripped during operation. It was found

that during field operation, a common hand tractor requires mild grip exertion leading to 6% to 14% activation of forearm muscles [42]. The influence of constant and long-term exposure to vibration (11.90 ± 10.17 years of farm-related work), even with mild grip exertion, led to such physical symptoms to farm operators. This is further supported by a significantly moderately positive correlation between operator's age and MSD symptoms like neck, back, and hand or wrist pains.

Finally, it was found that existing MSD symptoms moderately limited the daily activities and general lifestyle of the operators. Some of them have reported that, in the past 12 months, they needed to go to the hospital, take medications, skip work, or basically unable to perform their daily tasks.

B. Prevalence of HAVS Symptoms and their Correlation with Demographic Variables

After analyzing the data from the NMQ-E and figuring out that most of the MSD symptoms are on the upper limb, the Cold Intolerance Symptom Severity (CISS) test was assessed to see if hand-arm vibration syndrome (HAVS) symptoms were present. The CISS scores showed that about 85% of the operators have no signs of cold intolerance or HAVS and about 10% have mild signs. Similar to a previous study, the combined effects of constant mild muscle exertion and handle vibration, although at short-term exposure, did not show any significant influence on the perceived upper limb discomfort [33].

Nevertheless, the present study investigated the long-term effects of these stressors. It may appear to support that even at mild upper limb muscle exertion, when the exposure is constant and continuous for a long period, HAVS symptoms tend to manifest like MSD (as presented in the previous subsection). To support this, it was found that demographic variables such as the number of hours operating a tractor (2- or 4-wheel), the number of years operating a tractor (2- or 4-wheel), and the time of the day the equipment is being used and HAVS symptoms have significantly moderate correlations.

C. Prevalence of CTS Symptoms and their Correlation with Demographic Variables

The presence of CTS was also tested using the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ). The report showed that mild severity ratings are evident on the common CTS symptoms like pain and discomfort, numbness, weakness, and tingling on the hands and wrists. This supports the apparent mild difficulty ratings when performing tasks that require grip and hand strength such as opening jar lids (58%), doing household chores (53%), and carrying or holding grocery baskets (50%). Meanwhile, a moderate severity on the weakening of manipulative dexterity was observed. This explains the higher percentage of moderate to very severe difficulty ratings when writing (50%) and buttoning of clothes (50%), which require good hand control and fine motor skills.

Correlation analyses showed that there were significant correlations primarily on the number of hours operating a tractor (2- or 4-wheel) and the number of years operating a tractor (2- or 4-wheel) and CTS symptoms suggesting that constant and long-term exposure influence the presence of CTS symptoms.

IV. PRACTICAL IMPLICATIONS AND RECOMMENDATIONS

In general, the prevalence of mild to moderate MSD and CTS symptoms was associated with constant and long-term exposure to vibration as characterized by the reported farm-related work experience of the participants and required handle grip exertion in a related study [42]. Correlation analyses suggest that significant correlations are present between length of experience and vibration-related illnesses. Other related studies show that higher prevalence or severe effects are evident when stronger or harder force (grip) exertion or higher vibration acceleration is applied. In a study conducted in Pakistan that assessed the prevalence and risk factors of musculoskeletal pain (MSP) among construction workers through NMQ-E, it was identified that they suffered high prevalence of MSP which also affected their day-to-day functions highlighting several socioeconomic and ergonomic interventions to be considered [32]. Meanwhile, the prevalence of CTS was also observed in the medical field using BCTQ, in which CTS exist at 25.3% of the medical laboratory staff in King Saud University Hospitals, KSA. Furthermore, it was also reported that 30.5% of the dentists working in Riyadh have either mild or severe symptoms related to CTS [34]. Prevalence of CTS among dairy parlor workers was also seen and it was around 16.6% [36], while CTS among grocery workers was at 23% [37]. This was also present among construction workers at a prevalence range of 8.2% to 9.2% [38].

With these findings, the long-term impact of constant and continuous exposure to agricultural machinery vibration can significantly lead to the onset of vibration-related illnesses. Hence, several recommendations based on the results were highlighted:

- *Ergonomic interventions on farming tools*. Since farming tools are the primary sources of risks in the agricultural sector, their design must be aided with ergonomic principles. Typical interventions include padded grips, adjustable handles, or other interventions that reduce excessive force. Moreover, mechanical aids must also be provided to reduce manual labor and repetitive movements [39].
- *Job rotation and scheduled rests.* Incorporating job rotation and scheduled breaks will relieve farmers from doing repetitive tasks for an extended period. Task variations throughout the day resulted in positive psychosocial health of farmers as they are not fixated on one type of job in a day [40].
- *Collaboration with agricultural cooperatives for shared resources*. Since most rural farmers do not have the correct equipment and means to ease their farming activities, sharing resources and equipment is a good option. Group training sessions can also promote ergonomic practices such as correct stretching exercises, proper working postures, and correct lifting techniques, and more importantly, promoting awareness among farmers [41].
- *Youth involvement.* Since the number of years operating the equipment was significantly correlated and age was moderately correlated to the symptoms, having an observable trend that as age increases, the farm operators become more prone to more severe or more frequent occurrence of symptoms of MSDs or vibration-related illnesses. Hence, involving younger operators would be useful in dividing the workload with the older ones and in minimizing the risks associated with old age.

V. RESEARCH LIMITATION

The study primarily focused on the physiological effects of vibration to the agricultural operators in Tarlac and Laguna, Philippines. The locations were chosen due to its primary livelihood which is farming. The questionnaires were used to assess the onset of symptoms related to whole body vibration and existence of hand-arm vibration syndrome. The study considered the level of pain on the operators' different body parts such as the neck, shoulder, back, elbows, hand and wrist, hips, knee, feet, and ankles, and focused on the upper limb such as arms, hands, and wrists. However, the onset was only based on the duration and prevalence of pain on the above-mentioned body parts. Further, the study did not consider the existence of vibration illnesses, instead only the symptoms were assessed.

Other factors such as presence of other works, age-related and chronic illnesses, difficulty of operating other agricultural machinery, type of work (manual, automated, semi-automated), and vibration level of the equipment used were only considered for exclusion and inclusion criteria but were not included in the computation of the onset. Also, the number of years operating the two kinds of tractor, the relationships between number of hours and the number of years operating a machine, the direct combined effect of the number of hours and number of years operating a machine were not included and tested. Additionally, other health effects caused by vibration exposure identified in related literature such as illnesses in the gastrointestinal tract, the female reproductive organs, the peripheral veins, the cochleo-vestibular system, and cardiovascular and peripheral areas [14, 35] were not evaluated in this study. The researchers recognize the importance of inclusion of these factors in the next phases of this baseline study.

VI. CONCLUSION

The present study showed that vibration-related illnesses, including MSD, CTS, and HAVS, among agricultural machinery operators are prevalent. The onset of upper limb MSD symptoms can be observed after 9 to 10 years of operation with a prevalence of 29% to 36%, mostly evident on the shoulder and back. Meanwhile, 30% to 40% of participants have mild severity of CTS symptoms. Moderate severity of CTS symptoms that weakened manipulative dexterity, is notable in 13% of the participants. This led to difficulty in writing and buttoning of clothes. Furthermore, the presence of mild HAVS symptoms through the CISS test was also reported. Finally, correlation analyses showed that there exist moderate correlations between some demographic information and symptoms of MSD, CTS, and HAVS. As such, recommendations including having ergonomic interventions on farming tools, having proper work-rest scheduling, collaborating with agricultural cooperatives for shared resources, and actively involving younger operators are suggested in order to minimize risks associated with these illnesses.

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