PAPER • OPEN ACCESS

Pattern of muscle contraction in different postures among Malaysia pineapple plantation workers

To cite this article: N F M Salleh *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **469** 012088

Pattern of muscle contraction in different postures among Malaysia pineapple plantation workers

N F M Salleh[1], E H Sukadarin[1*], N K Khamis[2] and R Ramli[3]

[1]Occupational Safety and Health Programme, Faculty of Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia.
[2]Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bandar Baru Bangi, Selangor,Malaysia.
[3]Engineering Technology (Electrical) Programme, Faculty of Engineering Technology, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia.

[*] Corresponding author: ezrin@ump.edu.my

Abstract. Lower extremity disorders is associated with prolonged and awkward postures such as kneeling, squatting and stooping. Current study aims to examine the risk factors of awkward postures among pineapple plantation workers in Malaysia by using Ovako Working Posture Analysis System (OWAS). The postural analysis output from OWAS is then compared and validated by using Surface Electromyography (sEMG). There are 103 pineapple plantation workers participated in this study with an average working experience of 1 to 3 years. Based on OWAS findings, it shows for an overall distribution, planting, manual weeding and harvesting are the tasks fell under Action Category (AC) 3 which indicating distinctly harmful and (AC) 4 which indicating extremely harmful. The readings of muscle activity during selected postures show that erector spinae and multifidus muscle are actively contracted during kneeling, squatting and stooping posture. The results from this study signify that long exposure to these postures can increase the likelihood of having WMSDs such as back pain and lower limb injuries among pineapple plantation workers. This study suggests that ergonomic intervention such as mechanization of tools and equipments should be implemented in order to eliminate or reduce poor postures. In case of incapability for any mechanization, adequate and effective training should be provided for the workers as they can apply the knowledge through their job.

1. Introduction
Agricultural or farming work is known as monotonous and physically demanding task [1,2, 3,4] . Recently, the prevalence of Work-related Musculoskeletal Disorders (WMSDs) in this sector has been strongly prominent with severe impacts to the workers [5,4,6]. Common clinical diagnoses among agricultural workers were lower limbs pain including low back pain, herniated lumbar discs, oesteoarthritis and knee arthritis [7,8].

Pineapple plantation areas in Malaysia are being expanding to meet the growing demand for its products. They are expected to double their export value from RM155 millions to RM320 millions, annually, by 2020 [9]. According to its enormous economy profit, Malaysia's plan to increase pineapple exports by exploring new land for pineapple crops is beneficial as it allows extensive job opportunities for community. However, the negative impact from this economy strategy is the increase of manual labour intensive works since pineapple plantation workers are still doing their work manually by using customary tools [2] . Aside from working without the aid from modern tools, pineapple plantation workers are also exposed to several kinds of detrimental and extreme postures [10]. Considering pineapple plant is a short grow-low crop on the land, working by stooping, squatting and kneeling are unavoidable [11].

Ergonomic studies have shown that work-related postures can cause varying degrees of discomfort and strain on the musculoskeletal system among agriculture workers [12, 13, 14, 15]. The examples of awkward postures are stooping [16, 17], squatting [18, 19] and kneeling [20, 21] and these specific postures physical activities are encountered in agricultural occupations. Previous research has consistently shown evidence that frequent exposure to prolonged stooping is one of major risk factors for low back problems [7,17], while a study by Yip et al., in 2004 showed that there is significant association between squat posture and low back pain or back injury [22]. On the other hand, it is verified that kneeling posture during work can initiate knee pain in working population and can lead to more severe disorders which is knee osteoarthritis [23].

Preventing of previous kinds of WMSDs is the main concern in ergonomics. In order to accomplish that concern, a device call Surface Electromyography (sEMG) is often applied in ergonomic studies. The main purpose is to measure physical risk factors and provides unique possibilities to get significant information, highly relevant from several ergonomic perspectives [24]. During prolonged or sustained muscle contractions, typical changes in sEMG, such as an increase in the amplitude or a shift in the frequency spectrum towards lower frequencies, can be observed [25]. The functions of sEMG to investigate muscle activity contraction during postures in occupational settings are varied. However, there are limits on this research on sEMG validation of awkward postures particularly in agricultural sector whereby this paper aims to (1) categorize and examine awkward posture risk factors that could contribute to musculoskeletal disorders among pineapple plantation workers and (2) to test the validity of postural risk factors results by using sEMG.

2. Methodology

2.1 Postural Analysis Assessment

Different observational methods have been developed for evaluating the degree of discomfort caused by different body positions or movements [26]. Ovako Working Posture Analysis System (OWAS) is a long-established postural observation method assessment. This method was developed by a group of workers in Finnish steel company in 1974 [27]. OWAS is based on observation, analyzing and controlling workers' insufficient and poor postures while performing their functions in their jobs [28]. It describes the whole body postures using four digit codes representing the position of back (4 options), arms (3 options), legs (7 options) and the load to be handled (3 options) [29]. The method offers a look-up table for translating the 4 digits code into 4 actions category. There are total of 252 possible combinations that can be derived and these combinations are categorized into 4 actions category [30].

2.2 Respondents for Postural Analysis Assessment

The study areas were located in Pahang, Malaysia and 3 different pineapple plantations were selected according to their similar nature of work. One hundred and three respondents with 1 to 3 year(s) of working experience (mean=1.21, SD=0.41) were participated in this study and their ages were ranged from 17 to 52 years old (mean=3.57, SD=1.57). The process cycle in pineapple plantation involved four main jobs; planting, maintaining crops, manual weeding and harvesting [10]. Frequent, extreme and worst postures of workers while executing these main jobs was observed. A digital camera was used to capture dynamic activities during certain job task and by examining a stand still photos, OWAS was conducted.

2.3 Validation by using sEMG

2.3.1 Subject. A 22-year old healthy male student (Body Mass Index (BMI) = 19.4), with no history of pain at the lower limbs and lower back has volunteered to participate in this experiment but the subject is not permitted to participate in any extreme activities in the past 24 hours before the test was conducted [18]. Prior to the study, the subject received verbal and written information about this research.

2.3.2 Data analysis and processing. sEMG measurement was used in this study to investigate the muscle reactions according to certain postures in this study at two muscles namely erector spinae and multifidus [31, 32]. The sEMG device from Shimmer Corporation of Ireland was used to collect analogue data of muscle activity with sample rate up to 1000Hz interfaced with two channels signal amplifier. The function was to record, store and analyze all the data regarding the muscle activity of the subject. The device was used to collect the signals continuously and data were transferred into a personal computer via Bluetooth wireless transmission in real time using Shimmer Sensing LabVIEW Instrument Driver. Raw sEMG signals were then analyzed in Math Lab software to obtain clean and smooth data. Once completion of erector spinae and multifidus muscle activity is recorded, then the signal reading graphs is obtained.

2.3.3 Procedure. In the beginning of each experiment session, subject was prepared for sEMG electrode placement. The selection of muscles for each posture are based on previous epidemiological studies [33, 34]. Prior to attaching the electrodes, skin impedance was reduced from 3MΩ to less than 500KΩ by shaving excess body hair and the dead cells and, non-conductor elements were removed by using alcohol cotton swab respectively [33]. After that, the sEMG electrodes were affixed at L4/L5 of erector spinae and multifidus muscle. To ensure that the sEMG protocols were complied, the settings of the sEMG system during the measurement was based on established board and guidelines from SENIAM [34]. As for this assessment, subject was required to maintain three types of postures which were stooping, squatting and kneeling in a given time. Subject was asked to simulate postures (stooping, squatting and kneeling) by repeating a set of ground touching while maintain the postures respectively for 5 minutes. Rests were given for every 5 seconds after 10 seconds of posture [16].

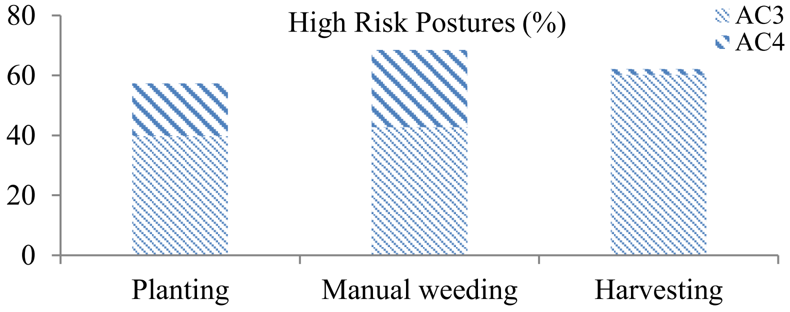
3. Results and Discussion

3.1 OWAS analysis

Table 1 listed the percentages of postures failing into AC 1, 2, 3 and 4 for all the job activities. OWAS identified postures during three activities; planting (39.8%), manual weeding (42.7%) and harvesting (60.2%) were categorized mainly in Action Category 3. Meanwhile, some postures from planting activity (17.5%) and manual weeding activity (27.2%) fell under Action Category 4 which indicated as extremely harmful. Figure 1 represents the percentages of poor postures for planting, manual weeding and harvesting. Poor working postures by pineapple plantation workers were observed frequently with 60.2% distinctly harmful postures during harvesting and 27.2% for extremely harmful posture during manual weeding activity.

Table 1. Postures of pineapple plantation workers for all jobs

N=103	Normal (%)	Slightly Harmful (%)	Distinctly Harmful (%)	Extremely Harmful (%)
Planting	15.5	27.2	39.8	17.5
Maintaining crops	59.2	39.8	0	0
Manual weeding	0	30.1	42.7	27.2
Harvesting	1.9	35.9	60.2	1.9



[a]AC= Action Categories
[b]Only maintaining crops was not listed under the category of extreme poor posture

Figure 1. High risk posture (Action Categories 3 and 4) for planting, manual weeding and harvesting process

It was identified that planting, manual weeding and harvesting were the major jobs with poor working posture exhibited by pineapple plantation workers. The most critical postures which associated with these three tasks were trunk (bend forward) and legs (squatting, stooping, and standing one leg bent).

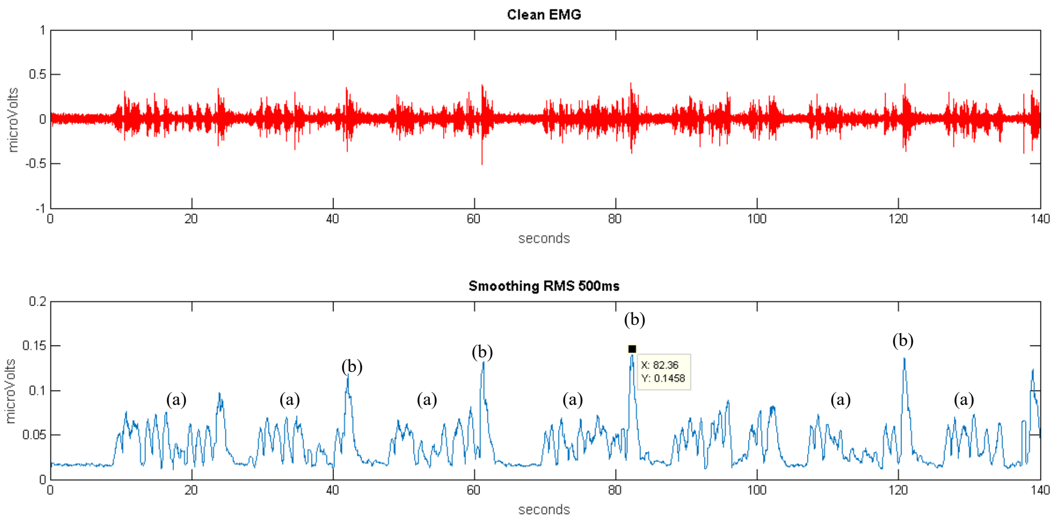
Specific to the task and nature of work in pineapple plantation, postural problems were the most common. Pineapple plantation workers were exposed to musculoskeletal problems such as lower back pain due to awkward and extreme postures. Gangopadhyay et al, (2005) revealed that common agricultural workers performed work constantly in awkward postures during certain job activities such as planting and manual weeding [13]. This claim can be supported by similar research done by Rani et al, (2016) and Ya'acob et al., (2018) which revealed that low back pain symptoms among pineapple plantation workers were linked with excessive bend posture during planting and manual weeding process [11, 35]. In addition, these workers work in long working hours by almost six hours of working and the constant exposure was consider prolonged and hazardous to the workers. Prolonged exposure can cause discomfort or pain in different parts of the body particularly the lower back, neck and knee regions [13].

Heavy lifting was significantly associated with lower back pain [36]. Harvesting process in pineapple plantation was consider strenuous, as the amount of weight carried by the workers was massive by 30-40 kg per basket. In a study of investigating postural risk factors among farmers by Beheshti et al., (2015), the results indicated that 77% of the body posture observed was harmful and only 23% was normal during harvesting [37]. A number of similar findings were also reported where risks of low back pain in agricultural sector were heavy physical work and awkward postures [4,5].

Based on OWAS analysis, frequent, awkward and extreme postures identified among pineapple plantation workers were stoop, kneel and squat posture. The reason is that pineapple plantation workers were required to bend low while working as the maximum height of pineapple crops was as tall as 1.5 meter from the ground. As they need to be working in a low ground situation, therefore, these postures are unavoidable.

3.2 sEMG analysis

To validate the result from OWAS, temporal analysis of muscle activity was conducted using sEMG. Figure 2 shows the temporal analysis graph of multifidus muscle for kneel posture. The highest peak of the signal is 0.14 microvolts at 829 seconds. Multifidus muscle was in active position during flexion of knees (b). However, the muscle was in rest position (a) during 5 seconds break. It was observed that during rest position (a), other muscle was actively contracted.



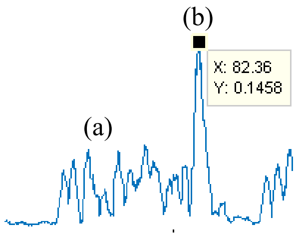
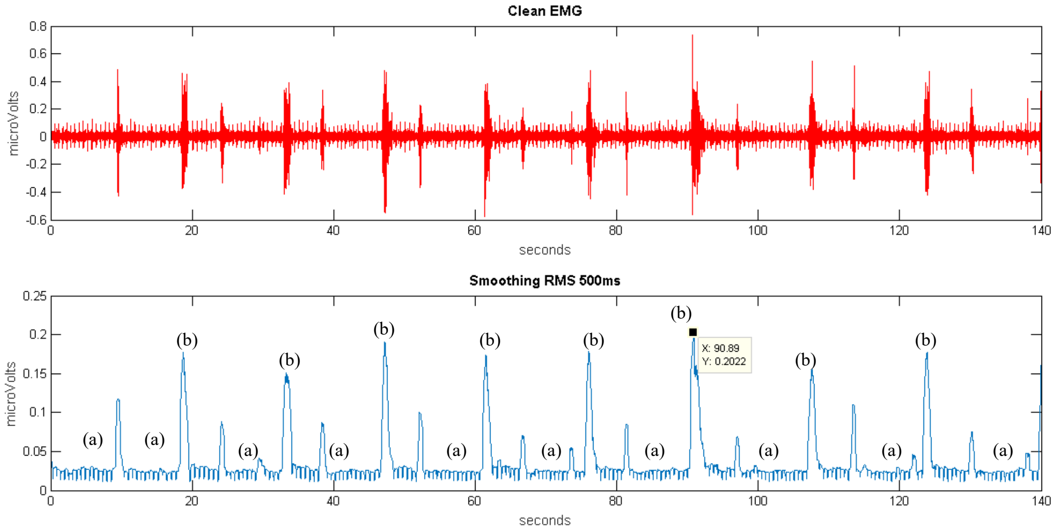
Graph points	Activity	
	 (a) Multifidus muscle was in rest position during 5 seconds break	 (b) Multifidus muscle was in active position during flexion of knees

Figure 2. Graph of clean sEMG and smoothing RMS – 500 ms multifidus (a) muscle rest; (b) muscle actively contracted

Pineapple plantation workers adapted prolonged kneeling posture particularly during planting activity for about more than 4 hours a day. In OWAS postural analysis result, 50.5% kneel postures were adapted from 52 pineapple plantation workers. According to Lomo-Tettey et al., (2013) their data on prolonged kneeling suggest that kneeling on two legs at 90 degrees of knee flexion over 10- 15 minutes starts changing muscle activation patterns, primarily in knee and torso flexor muscle groups [38]. It was further discussed that kneeling on two legs at 90 degrees of knee flexion over 30 minutes were primarily the hamstrings and abdominal muscles. This claim can be supported by D'Souza et al, (2008) who mentioned that just about 20.7% of knee osteoarthritis cases can be associated to male workers kneeling more than 14% of their workday [39].

The analysis of integrated sEMG activity of multifidus muscle appears to confirm that multifidus muscle is contracted during kneeling posture. The consequence of working in a kneeling posture and its association with knee osteoarthritis is described in numerous studies [40,41, 42]. A study by Baker et al., (2002) found that workers who spent more than 1 hour working in a kneeling posture were about twice likely to have knee osteoarthritis compared to workers who hardly ever work in kneeling position [43]. Meanwhile, there is association of kneeling posture and low back pain examined in one longitudinal study by Harkness et al., (2003) which discovered that there was a statistically significant increased risk of low back pain for workers who performed their work in kneeling posture for more than 15 minutes [44].

Figure 3 shows the temporal analysis graph of erector spinae muscle for stoop posture. The highest peak of the signal is 0.2 microvolts at 91 seconds. Erector spinae muscle was in active position during bending (b). However, the muscle was in rest position (a) during 5 seconds break. It was observed that during rest position (a), other muscle was actively contracted.



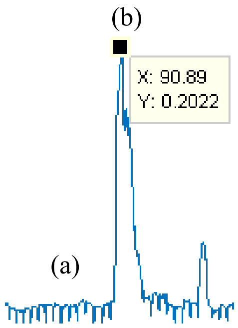
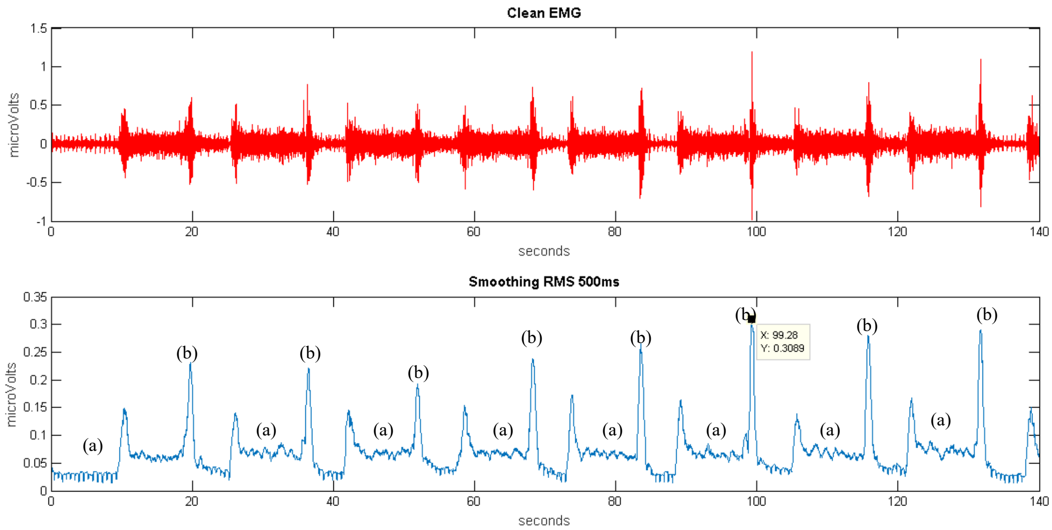
Graph points	Activity	
	 (a) Erector spinae muscle was in rest position during 5 seconds break	 (b) Erector spinae muscle was in active position during bending

Figure 3. Graph of clean sEMG and smoothing RMS – 500 ms erector spinae (a) muscle rest; (b) muscle actively contracted

A large number of pineapple plantation workers routinely performed stooping postures during their daily work activities. In OWAS postural analysis result, 62.1% stoop postures (trunk bent forward and straight legs) were adapted among 64 pineapple plantation workers during manual weeding while 67% were adapted among 59 pineapple plantation workers during harvesting activity. According to a stoop work task research by Miller and Fathallah (2006), there is a significant change in the trunk sagittal range motion after only 11 minutes of stooped work [45]. Shin and Mirka (2007) and Shin et al, (2009) claimed that during stooping posture, passive tissue creep in the hips and/or lower back (resulting in increased hip and/or lower lumbar flexion), requiring greater extensor moments from the hip and lower back muscles, thus contributing to muscle fatigue [46, 47]. This claim can also be supported by similar research done by Nou et al., (2012) which concluded that both cyclic and stooped work conditions are equally harmful to the spine [16].

The analysis of integrated sEMG activity of erector spinae muscle appears to confirm that erector spinae muscle is contracted during stooping posture. Prolonged or cyclic work in stooped postures is a known risk factor for developing low back disorders [48, 7] . In a review of working in stoop postures of agricutural production by Miller and Fathallah (2018), it can be concluded that there is sufficient evidence supporting working in stoop postures exposed a large segment of agricultural workers to a high risk of developing low back disorders [45]. Nonetheless, stooping posture is frequently chosen over kneeling or squatting because the stooped posture allows for greater motility and reach [49].

Figure 4 shows the temporal analysis graph of erector spinae muscle for squat posture. The highest peak of the signal is 0.31 microvolts at 99 seconds. Erector spinae muscle was in active position during squatting (b). However, the muscle was in rest position (a) during 5 seconds break. It was observed that during rest position (a), other muscle was actively contracted.



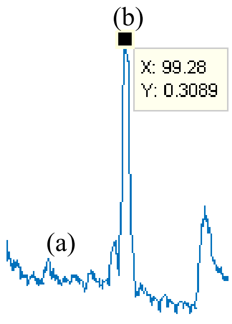
Graph points	Activity	
	 (a) Erector spinae muscle was in rest position during 5 seconds break	 (b) Erector spinae muscle was in active position during squatting

Figure 4. Graph of clean sEMG and smoothing RMS – 500 ms erector spinae (a) muscle rest; (b) muscle actively contracted

The analysis of integrated sEMG activity of erector spinae muscle appeared to confirm that erector spinae muscle was contracted during kneeling posture. In OWAS postural analysis result, 35.9% squat postures were adapted from 29 pineapple plantation workers during planting activity. According to Kim et al., (2014) normalized sEMG activity in erector spinae during squatting was significantly higher in risk for LBP [50]. However, this claimed can be contended by Xiao et al., (2015), who indicated that in squatting down task, sEMG activities in vastus lateralis muscle were significantly greater that eretor spinae, hence, a person will feel fatigue more easily in lower limbs than in lower back [18]. Epidemiologically study also showed frequent or prolonged squatting doubles the general risk of knee osteoarthritis [40].

In consideration of results found in this study, some proposed recommendations in preventing the postural risk factors of WMSDs were addressed. Development and ergonomic intervention programmes such as modification of tools or equipments should be implemented to increase the efficiency and to allow reduction of exposure. Besides, adequate and effective training should be provided among pineapple plantation workers in order for them to perform their job in safely ways. After all, the risk exposure for workers must be reduce in terms of work load, duration of work and prolonging rest time by alternating work tasks particularly between physically demanding work tasks or to rotate job activities among different workers so that the maximum allowable exposure is restricted

4. Conclusion

This study highlighted awkward and extreme postures in Malaysia pineapple plantation and the muscles involved with possible WMSDs. The findings show that manual weeding is the most high risk task as it involves extreme postures which required trunk to bent and twisted while arms are sometimes above shoulder height. Planting activity is also considered as high risk for it occupies prolonged and repetitive awkward postures.

Validation test by using Surface Electromyography reveals that such awkward postures that are adapted by pineapple plantation workers can harm and expose them to musculoskeletal problems. Stooping, kneeling and squatting can caused back pain, knee pain, osteoarthritis and other lower extremity problems to workers. The muscle activities of associated muscles with the posture (stooping, kneeling, squatting, and lifting) convinced that the exposure level data obtained from OWAS is valid thus can support this study results.

Acknowledgement

This project is financially funded by the grant of Knowledge Transfer Programme (KTP) under the Ministry of Higher Education, Malaysia (Grant No: RDU161002) and also supported by Universiti Malaysia Pahang (www.ump.edu.my).

References

[1] Das B and Gangopadhyay S 2011 *Occupational Ergonomics*. **10** 25–38
[2] Tamrin S B M and Aumran N 2014 *Occupational Safety and Health in Commodity Agriculture: Case Studies from Malaysian Agriculture Perspective.* **1** 93–146
[3] Fathallah F A 2010 *Applied Ergonomics.* **41** 738–743
[4] Kirkhorn S R, Earle-Richardson G and Banks R J 2013 *Journal of Agromedicine.* **15** 281-299
[5] Osborne A, Blake, Ã C, Fullen, B M, Meredith D, Phelan J, Mcnamara J and Cunningham C 2012 *American Journal Of Industrial Medicine.* **55** 376–389
[6] Sukadarin E H, Deros B D, A.Ghani J and Ismail A R 2013 *Australian Journal of Basic & Applied Sciences.* **8** 56-59
[7] Fathallah F A, Miller B J and Miles J A 2008 *Journal of Agricultural Safety and Health.* **14** 221–245
[8] Da Costa, B R and Vieira E R 2010 *Am J Ind Med.* **53** 285–323
[9] Jamal, A A 2017 Pineapple export increase by 2020. Berita Harian (online) https://www.bharian.com.my/node/282205
[10] Salleh N F M and Sukadarin E H 2018 *MATEC Web of Conferences.* **150** 05047
[11] Rani N H, Abidin E Z, Ya'acob N A and Karuppiah K 2016 *Journal of Occupational Safety and Health.* **13** 17–26
[12] AuYong H N 2016 *International Conference on Agricultural and Food Engineering* (August). 382-386
[13] Gangopadhyay S, Das D, Das T and Ghoshal G 2015 *International Journal of Occupational Safety and Ergonomics*. **11** 315-322
[14] Sukadarin E H, Deros B D, A.Ghani J and Ismail A R 2013 *Australian Journal of Basic & Applied Sciences.* **8** 56-59

[15] Meyer R H and Radwin R 2007 *Applied Ergonomics.* **38** 549–555
[16] Nou D, Miller B J and Fathallah F A 2012 *Proceedings of the Human Factors and Ergonomics Society.* 1196–1200
[17] Zhu X and Shin G 2013 *Journal of Electromyography and Kinesiology.* **23** 801–806
[18] Xiao J, Gao J, Wang H, Liu K and Yang X 2015 *Physiological Journal.* 1-6
[19] Chung M K, Lee I, and Kee D 2005 *Ergonomics.* **48** 492–505.
[20] Ditchen D M, Ellegast R P and Rieger M A 2015 *Int Arch Occup Environ Health.* **88**153–165
[21] Reid C R, McCauley Bush, P, Karwowski W and Durrani S K 2010 *International Journal of Industrial Ergonomics.* **40** 247–256
[22] Yip Y B, Ho S C and Chan S G 2004 *Health Care Women Int.* **25** 358–369
[23] Tennant L M, Chong H C and Acker S M 2018 *Ergonomics.* **61** 839-852
[24] Hägg G M, Luttmann A, and Jäger M 2000 *Journal of Electromyography and Kinesiology.* **10** 301–312
[25] Luttmann A, Jager M, Griefahn B, Caffier G, and Liebers F 2003 *Protecting Workers' Health Series* No. 5
[26] Takala E-P, Pehkonen I, Forsman M, Hansson G-å, Mathiassen S E, Neumann, W P, Sjøgaard G, Veiersted K B, Westgaard R H and Winkel J 2010 Scand J Work Environ Health. **36** 3–24
[27] Karhu O, Kansi P, and Kuorinka I 1977 *Applied Ergonomics.* **8**199–201
[28] Lee T H and Han C S 2013 *International Journal of Occupational Safety and Ergonomics.* **19** 245–250
[29] Chander D S and Cavatorta M P 2017 *International Journal of Industrial Ergonomics*. **57** 32–41
[30] Tortato Novaes A L, de Andrade G J P O, Alonço A dos S and Magenta Magalhães A R 2017 *Aquacultural Engineering*. **77** 112–124
[31] Hwang S, Kim Y and Kim Y 2009 BMC Musculoskelet Disorder. **10**
[32] Pirouzi S, Emami F, Taghizadeh S and Ghanbari A 2013 *Iran J Med Sci December.* **38** 327-333
[33] Lee D, Kim Y, Yun J, Jung M and Lee G 2016 *Journal of Physical Therapy Science.* **28** 1478–1481
[34] Stegeman D and Hermens H 2007 Standards for surface electromyography: The European project Surface EMG for non-invasive assessment of muscles (SENIAM)(online).http://www.seniam.org/%5Cnhttp://www.med.unijena.de/motorik/pdf/stegeman.pdf
[35] Ya'acob N A, Abidin E Z, Rasdi I, Rahman A A and Ismail S 2018 *Work* . **60** 143–152
[36] Młotek M, Kuta Ł, Stopa R and Komarnicki P 2015 *Procedia Manufacturing*. **3** 1712–1719
[37] Beheshti M H, Firoozi Chahak A, Alinaghi Langari A A and Poursadeghiyan M 2015 *Journal of Occupational Health and Epidemiology*. **4** 130–138
[38] Lomo-Tettey D, Campbell-Kyureghan N, Johnson B and Beschorner K n.d. *Spine Biomechanics Laboratory of University of Wisconsin-Milwaukee, WI, USA*. **16** 1–2
[39] D'Souza J C, Werner R A, Keyserling W M, Gillespie B, Rabourn R and Ulin S 2008 *Am J Ind Med.* **51** 37–46
[40] Manninen P, Heliövaara M, Riihimäki H and Suomalainen O 2002 *Scandinavian Journal of Work, Environment and Health.* **28** 25–32
[41] Yoshimura N, Nishioka S, Kinoshita H, Hori N, Nishioka T and Ryujin M 2004 J Rheumatol **31** 157-162
[42] Lau ECC 2000 *Am J Epidemiol.* **152** 855–862.
[43] Baker P, Coggon D, Reading I, Barret D, McLaren M and Cooper C 2002 *J Rheumatol.* **29** 557–563
[44] Harkness E F, Macfarlane G J, Nahit ES, Silman A J and McBeth J 2003 Rheumatology(Oxford). **42** 959-968
[45] Miller BJ and Fathallah FA 2018 *ASAE Annual International Meeting.* 6357–6372
[46] Shin G and Mirka G A 2007 *Clinical Biomechanics.* **22** 965–971
[47] Shin G, D'Souza C and Liu YH 2009 *Spine (Phila. Pa. 1976)*. **34** 1873–1878

[48] McCurdy S A, Samuels S J, Carroll D J, Beaumont J J and Morring L A 2003 *American Journal of Industrial Medicine*. **44** 225–235
[49] Fathallah F A, Meyers J M and Janowitz I 2004 *Conference Proceedings. University of California Center for Occupational and Environmental Health, Oakland, California*
[50] Kim J W, Kwon O Y, Kim T H, An D H and Oh J S 2014 *Manual Therapy.* **19** 467–471