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EDITORIAL PREFACE

This is the *First* Issue of Volume *Three* of International Journal of Ergonomics (IJEG). The Journal is published bi-monthly, with papers being peer reviewed to high international standards. The International Journal of Ergonomics is not limited to a specific aspect of Ergonomics but it is devoted to the publication of high quality papers on all division of engineering in general. IJEG intends to disseminate knowledge in the various disciplines of the Computer Science field from theoretical, practical and analytical research to physical implications and theoretical or quantitative discussion intended for academic and industrial progress. In order to position IJEG as one of the good journal on Computer Sciences, a group of highly valuable scholars are serving on the editorial board. The International Editorial Board ensures that significant developments in Ergonomics from around the world are reflected in the Journal. Some important topics covers by journal are architectures, middleware, tools designs, Experiments, Evaluation, etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 3, 2013, IJEG appears with more focused issues. Besides normal publications, IJEG intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

The coverage of the journal includes all new theoretical and experimental findings in the fields of engineering which enhance the knowledge of scientist, industrials, researchers and all those persons who are coupled with engineering field. IJEG objective is to publish articles that are not only technically proficient but also contains information and ideas of fresh interest for International readership. IJEG aims to handle submissions courteously and promptly. IJEG objectives are to promote and extend the use of all methods in the principal disciplines of Computing.

IJEG editors understand that how much it is important for authors and researchers to have their work published with a minimum delay after submission of their papers. They also strongly believe that the direct communication between the editors and authors are important for the welfare, quality and wellbeing of the Journal and its readers. Therefore, all activities from paper submission to paper publication are controlled through electronic systems that include electronic submission, editorial panel and review system that ensures rapid decision with least delays in the publication processes.

To build its international reputation, we are disseminating the publication information through Google Books, Google Scholar, Directory of Open Access Journals (DOAJ), Open J Gate, ScientificCommons, Docstoc and many more. Our International Editors are working on establishing ISI listing and a good impact factor for IJEG. We would like to remind you that the success of our journal depends directly on the number of quality articles submitted for review. Accordingly, we would like to request your participation by submitting quality manuscripts for review and encouraging your colleagues to submit quality manuscripts for review. One of the great benefits we can provide to our prospective authors is the mentoring nature of our review process. IJEG provides authors with high quality, helpful reviews that are shaped to assist authors in improving their manuscripts.

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Reducing Low Back Pain in Construction Works; A Fuzzy Logic Approach

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Abstract

In this study, a fuzzy linguistic model was developed to reduce the risk of Low back Pain (LBP) in construction works. The primary objective was to develop a computer-based model for risk assessment capable of generating results which are comparable more efficient than those obtained manually by human experts' calculations. The expert system used fuzzy set theory to make decisions about the level of risk associated with selected worker. Posture at work, frequency of lift and weight of load were the three constituent elements of input used while the output is risk of LBP. The result of validation shows that there was a strong positive relationship between the calculated human experts' LBP risk and that of the model with correlation coefficient of 0.934. It can thus be concluded that though conventional mathematical modeling has been a recognized tool in ergonomic evaluation, a fuzzy model system also generate a very helpful results in, minimizing risk involved in construction tasks and, determining effective means of deploying personnel.

Keywords: Fuzzy, Expert, Back, Pain, Construction.

1. INTRODUCTION

Low back pain (LPB) is pain and stiffness in the lower back. It is usually caused when a ligament or muscle holding a vertebra in its proper position is strained [1]. Low back pain (LBP) is the most prevalent musculoskeletal disorders (MSDs) [2]. It is the most common disabling musculoskeletal symptom [3] and the most commonly reported on-site job-related MSDs [4].

Occupations most likely to experience LBP injury because of manual lifting include labourers, assemblers, carpenters, painters, bricklayers, plasterers, joiners and plumbers [5-7]. Oude [8] stated that, in a population of working construction workers, majority suffered from occasional or frequent musculoskeletal complaints. According to [9] complaints of the back and elbow were the most often reported among bricklayers during work and the majority of the construction workers believe that their complaints are work-related. Lower back complaints among bricklayers might be related to lifting and carrying [10]. Many construction workers believe that their LBP is caused by manually lifting of heavy loads during work time and most of them experience that they have little control to solve the causes of their problem [11]. It was earlier affirmed that greater workloads increase mechanical stress (and thus strain) to the cause of LBP [12]. There are a number of factors that may make a manual material task hazardous in construction work, particularly for the development of LBP; awkward posture, frequency of lift and load [13-16], uncomfortable working position, working too long without break, adverse working environment, psychosocial factors [17] were mentioned as potential risk factors. It was stated that many other medical problems can contribute to musculoskeletal disease [18].

Lifting index appears to be a useful indicator for determining the risk of LBP caused by manual lifting [19]. NIOSH Lifting Equation is valid job analysis method to predict risk for low back injury [20]. It is a tool for evaluating the physical demands of two-handed manual lifting tasks which consists of two equations: the recommended weight limit (RWL) and the lifting index (LI) for evaluating some specific manual lifting tasks. The computation of RWL required measurement and input of parameters that describe the task such as location of hands, frequency of lifting, type of hand coupling required for the task, work duration and weight of load lifted. The LI is defined as the ratio of the actual weight of the load (L) lifted divided by the RWL for the job (LI=L/RWL). It gives an estimate of the relative physical demand for the task. Lifting tasks with a LI greater than 1.0 pose an increased risk for lifting-related pain. If the magnitude of the LI increases: the level of the risk for the worker performing the job would be increased; and a greater percentage of the workforce is likely to be at risk for developing lifting-related LBP. LI greater than 3 was considered to have the highest risk [21-22].

To retain workers in the construction field, it is essential to select potentially effective intervention measures and prevent the workers from further physical deterioration [9]. According to [23], every (extra) ergonomics measure implemented for LBP prevention might be profitable.

1.1 The Aim and Objective of The Proposed Study

The objective of the proposed study is to develop a fuzzy rule based model for LBP risk evaluation which traditional methods are unable to offer effectively. The study aimed to find out;

i. If there is a significant difference between the LBP risks calculated by human experts and that predicted by the model.

ii. If there is any difference in assessment results between human experts opinions and that of the fuzzy logic evaluation technique.

2. MATERIALS AND METHODS

2.1 Fuzzy Set Theory

The focus of attention of this study is the reduction of LBP risk involved in construction work using fuzzy logic based expert system for risk assessment of tasks involving manual lifting. A fuzzy system is a static nonlinear mapping between its inputs and outputs. Application of fuzzy modeling to ergonomics is becoming popular. Among many successful attempts, [24] used fuzzy as a tool to minimizing MSDs in Lathe machine workers using two input variables (frequency of lift and lifting height). A fuzzy technique was applied by [25] to develop a model for evaluating fatigue using data from several estimators of fatigue. A combination of probability and fuzzy set theory were used by [26] to handle the uncertainties in health risk assessment. Fuzzy reasoning algorithm was adopted by [27] to assess and predict cumulative trauma disorders occurrence in workplace.

It is assumed that the fuzzy system has inputs $u_i \in U_i$ where i = 1, 2. . . n and outputs $y_i \in Y_i$ where i = 1, 2, . . .,m, as shown in Figure 1. The inputs and outputs are “crisps”. The fuzzification block converts the crisp inputs to fuzzy sets, the inference mechanism uses the fuzzy rules in the rule-base to produce fuzzy conclusions and the defuzzification block converts these fuzzy deductions into the crisp outputs [28].

According to [29], if X is a set serving as the universe of discourse, a fuzzy subset A of X is associated with a function which is generally called membership function. For each x, $m_A(x)$ indicates the degree to which x is a member of the fuzzy set A. This membership degree indicates the compatibility degree of the assertion "x is A".

$$\mu_A : \times \to [0,1] \quad (1)$$

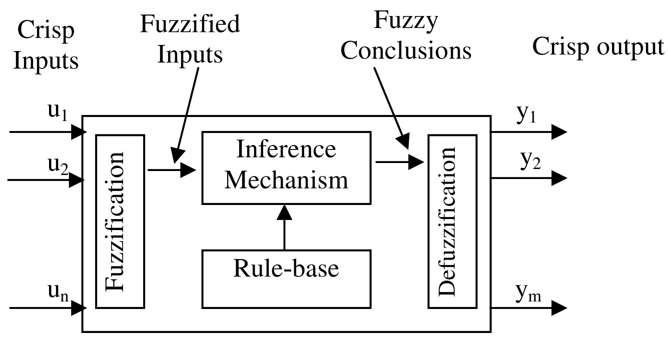

FIGURE 1: Fuzzy System Block Diagram [24].

If one assumes that A and B are two fuzzy subsets of X, their standard intersection, union and complement are also fuzzy sets given by:

$$\mu_{A \cap B}(\times) = \min[\mu_A(\times), \mu_B(\times)] \quad (2)$$

$$\mu_{A \cup B}(\times) = \max[\mu_A(\times), \mu_B(\times)] \quad \text{And} \quad (3)$$

$$\mu_{\underline{A}}(\times) = 1 - \mu_A(\times) \quad (4)$$

Where $\underline{A}$ is the negation of A (not A).

Intersection, union and complement defined above are fuzzy operators that one can use to combine fuzzy variables to form fuzzy expressions, as aggregating fuzzy rules.

In this study we used trapezoidal membership function for converting the crisp set into fuzzy set. Trapezoidal fuzzy numbers of the form (a, b, c, d) are more generalized form of membership functions and the most generic class of fuzzy numbers with linear membership function. The parameters a and d locate the "feet" of the trapezoid and the parameters b and c locate the "shoulders" [30]. This class of fuzzy numbers has more applicability in modeling linear uncertainty in scientific and applied engineering problems [31].

2.2 Study Site And Task Selection

2.2.1 Description of Study Area

Five construction sites located in the Southwestern Nigeria were used for the study. These included; the development of a factory along Ijoko road with 54,750 square meter area and a proposed ware house development at Agbara in Ota Local government area. Ado-Odo/Ota borders on metropolitan Lagos at 6°41′00″N 3°41′00″E / 6.6833333°N 3.6833333°E / 6.6833333; 3.6833333 to the north of the Area. The other three sites were situated in Abeokuta town. Abeokuta is the largest city and capital of Ogun State in southwest Nigeria. It is situated at

WikiMiniAtlas 7°9′39″N 3°20′54″E / 7.16083°N 3.34833°E / 7.16083; 3.34833 Coordinates: 7°9′39″N 3°20′54″E / 7.16083°N 3.34833°E / 7.16083; 3.34833, on the Ogun River; 64 miles north of Lagos by railway, or 81 miles by water.

The climatic conditions prevailing over the study areas in the ecosystems were mainly those of the tropical rainforest, typified by an average annual temperature 30 ± 100C, relative humidity of 65 ± 10% and an average annual rainfall of 1500±120mm [32].

2.2.2 Task Selection

Tasks for study were selected based on the following criteria:

- Manual lifting single-task performed regularly with at least 30 lift in a day
- Task performed for a long time without major changes in pattern
- Task that conform to the application of the RWL (i.e. which does not involve one-handed or seated lifting, handling unstable objects, none required of significant amount of non-lifting physical demands). Tasks including pushing, pulling, carrying, walking and climbing were not included in the study because they required significant energy expenditure.

Twenty nine lifting-related jobs were included in the study involving one hundred and twenty healthy male workers. Eight jobs were identified in the first construction site (CS) were workers lift concrete bricks weighing between 15 and 24kg. The lifting were identified in; brick setting, kerb setting, lowering bricks from truck bed, loading wheelbarrow with bricks (workers pushing wheelbarrow were not involved in the study). Another 7 jobs were identified in the second CS were workers lift concrete mortars during column/beams/slab filling task. The loads lifted typically weighed 25-30kg. Another 5 jobs were recorded in the third site. The weight of the material lifted ranges between 2.5 and 14kg. The jobs included lifting identified in fixing; window blade, ceiling fan, fluorescent holders and lifting steel to be cut into sizes on a cutting machine. Five jobs were discovered in the fourth site were workers were required to lift 2 - 7kg load. Jobs in this category included lifting during fixing of interlocking concrete pavers and tilling. Finally 4 jobs were recorded in the fifth CS and the load ranged between 5.5 and 42kg. The jobs included stacking/dis-stacking material into/from site store, lifting wooden doors.

2.3 Data Collection For Development of The Fuzzy Based Model

The data collection was conducted at the workers' workplace during the working period and at a time supported by the workers and the management. According to [33], reliable measurements are obtained if standardized measurement methods are used. For reliability, trained personnel were involved in the measurement of variables of the selected single-tasks. Workers were observed to record the task time. In each of the selected job the following variables were recorded: weight of the lifted object (kg) using a weighing scale, frequency of the lift (lift/min) with the use of stop watch, task duration (hour) with wrist watch, vertical and horizontal distances (cm) both at the origin and destination of the lift with meter rule, coupling rating by observation, asymmetry angle (degree) both at the origin and destination of the lift with the use of goniometer. Three sets of measurements were made for each worker and the frequency of lift was counted within the sample period of 15minutes.

For the purpose of validation, data obtained from the workers were used for the calculations of single-task lifting index. All the tasks were analyzed both at the origin of lift and at the destination. This is to obtain maximum possible values of LI for the jobs. Since there is no procedure for computing the LI for jobs with extreme variability, in jobs which the frequency of lift exceeded 10lift/min, a minimum LI value was computed for the critical case since above this value the frequency multiplier is set to zero and LI approaches infinity hence may not be used to distinguish between tasks. This procedure was also used for tasks in which the horizontal height exceeded 63cm. However doing this may result into an underestimation of risk involve in the task.

2.4 Techniques of The Proposed Fuzzy Logic Expert System

One of the shortcomings of the traditional evaluation methods is the insufficient information about what criteria used for the 'final result' [34]. This fuzzy approach of LBP evaluation will allow a more realistic modeling of variable status for output result and assists in determining the exact degree of a particular concept use for decision making by the users.

Low back Pain risk evaluation with the proposed fuzzy based model comprised with three steps:

1. Identification and Fuzzification of LBP risk factors and output risk value.

2. Formation of linguistic rules and inference mechanism.

3. Defuzzification of LBP risk value.

Step 1:- Three major lifting task risk factors; weight of load lifted (kg), posture at lift (asymmetric) (degree) and lifting frequency (lift/min) were selected as input variables for the model. The choice of these variables agreed with the view of [14-15] who identified these factors as the prominent risk factors in manual material lifting in the construction works. These variables were operationally defined as described in the revised NIOSH lifting equation. The classifications of the variables (Tables 1-2) were derived by finding the k-th percentile of values in the range of multipliers provided in the revised NIOSH lifting equation [35] for asymmetric and frequency. The same technique was adopted in the classification of load variable (Table 3) using a modified version of the study results relating linguistic terms and amount of load handled reported by [36].
The model was developed from an expert knowledge, who detailed five linguistic values to the variable Asymmetric: Extremely high deviation (EHD), Very high deviation (VHD), High deviation (HD), A little high deviation (AHD), Low deviation (LD).

K-th Percentile	Class Mid-point	Linguistic Term	Interval
0	0	Low deviation (LD)	0, 0, 1, 32.8
25	33.8	A little high deviation (AHD)	1, 32.8, 34.8, 66.5
50	67.5	High deviation (HD)	34.8, 66.5, 68.5, 100.3
75	101.3	Very high deviation (VHD)	68.5, 100.3, 102.3, 127.3
95	128.3	Extremely high deviation (EHD)	102.3, 127.3, 135.0, 180

Modified version of the range of asymmetric multipliers provided in the revised NIOSH lifting equation by [35].

TABLE 1: Fuzzy Set of Input Variable 'Posture'.

Five linguistic values to the variable Frequency of lift: Excessive high frequency (EHF), Very high frequency (VHF), High frequency (HF), Moderate frequency (MF), Low frequency (LF).

K-th Percentile	Class Mid-point	Linguistic Term	Interval
0	0.2	Low freq.(LF)	0, 0.15,0.25, 1.5
25	2	Moderate freq. (MF)	0.25, 1.5, 2.5, 4.5
50	5	High freq.(H)	2.5, 4.5, 5.5, 7.5
75	8	Very high freq.(VHF)	5.5, 7.5, 8.5, 10.5
100	>11	Extremely high freq.(EHF)	8.5, 10.5, 15, 15

Modified version of the range of frequency multipliers provided in the revised NIOSH lifting equation by [35]

TABLE 2: Fuzzy Set of Input Variable 'Frequency'.

Five linguistic values to the variable Load: extremely heavy load (EHL), heavy load (HL), moderate load (ML), light load (LL), and negligible load (NL).

K-th Percentile	Class Mid-point	Linguistic Term	Interval
0	0	Negligible load(NL)	0, 0, 0.5, 3.5
25	4.5	Light load(LL)	0.5,3.5, 5.5, 13
50	14	Moderate load (ML)	5.5, 13, 15, 31
75	32	Heavy load (HL)	15, 31, 33, 55
100	56 and above	Extremely heavy load (EHL))	33, 55, 110, 110

Modified version of the study results relating linguistic terms and amount of load handled by [36]

TABLE 3: Fuzzy Set of Input Variable 'Load'.

The consequence of the model is the risk of LPB. The experts [19] considered five linguistic values (Table 4) for the classification: No risk (NR), Low risk (LR), Medium risk (MR), high risk (HR) and Extremely high risk (EHR).

Range	Linguistic Term	Interval
0	No Risk (NR)	0,0,0,0
0-1	Low Risk (LR)	0,0,1,1.1
1-2	Medium Risk (MR)	1,1.1,2,2.1
2-3	High Risk (HR)	2,2.1,3,3.1
>3	Very High Risk (VHR)	3,3.1,5,6

Modified experts' opinions reported by [19].

TABLE 4: Fuzzy Set of Output Variable 'LBP risks'.

Step 2:- With the three inputs and five linguistic values for each, there are 125 rules (all possible combinations of premise linguistic values) used for the model. Some of the rules are stated below;

If (Posture is LD) and (Frequency is LF) and (Load is NL) then (Risk-of-LBP is NR)

1. If (Posture is LD) and (Frequency is HF) and (Load is NL) then (Risk-of- LBP is LR)
2. If (Posture is AHD) and (Frequency is MF) and (Load is NL) then (Risk-of- LBP is LR)
3. If (Posture is LD) and (Frequency is EHF) and (Load is NL) then (Risk-of- LBP is MR)
4. If (Posture is VHD) and (Frequency is LF) and (Load is NL) then (Risk-of- LBP is MR)
5. If (Posture is AHD) and (Frequency is HF) and (Load is LL) then (Risk-of- LBP is HR)
6. If (Posture is HD) and (Frequency is HF) and (Load is LL) then (Risk-of- LBP is HR)
7. If (Posture is HD) and (Frequency is HF) and (Load is LL) then (Risk-of- LBP is HR)

" " " "

125. If (Posture is HD) and (Frequency is EHF) and (Load is LL) then (Risk-of- LBP is VHR)

The procedure of the fuzzy linguistic model, given three of the above inputs for any category of the workers, consists of calculating the membership degree of these values in all fuzzy sets of the input variables.

Step 3:- The risk of LBP is determined by inference of the fuzzy rule set, using Mamdani's inference and centroid defuzzification of the fuzzy output. Mamdani's method was proposed in 1975 by Ebrahim Mamdani and it is the most commonly seen fuzzy methodology. The technique is intuitive, has widespread acceptance and is well suited to human input [30, 37]. Centroid defuzzification method was developed by Sugeno in 1985. It is also the most commonly used technique and it is been proved to be very accurate [38].

3. RESULTS AND DISCUSSIONS

One hundred and twelve (93.3%) of the 120 workers that participated in the study completed the questionnaire all of which have spent not less than 2 years on the current job. The demographics of the workers who participated in the studies are presented in Table 5.

	Mean	**SD***	**Range**
Age (yrs)	36.87	5.76	26-49
Duration of employment	5.87	2.49	2-12

*SD= Standard Deviation.

TABLE 5: An Overview of The Demographic Information of The Workers Studied In Five Construction Sites (n=112).

The model was run on Matlab 7.8 using several values of the input variables to obtain the results of the mapping of the system. Figure 2 to 5 showed the membership function graphs which display for inspection and modification of all the membership functions associated with all of the input and output variables for the entire fuzzy based model inference system.

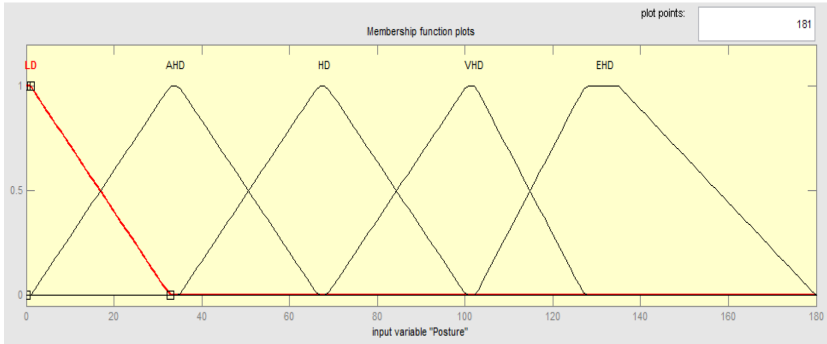

FIGURE 2: Membership function editor describing all membership functions for the input variable 'Posture'.

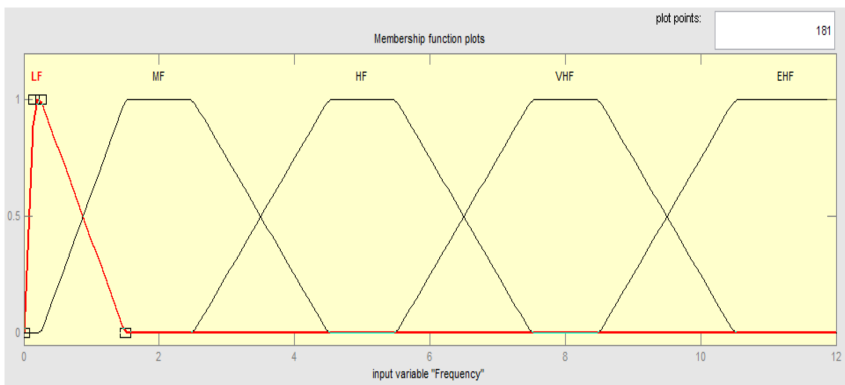

FIGURE 3: Membership function editor describing all membership functions for the input variable 'Frequency of Lift'.

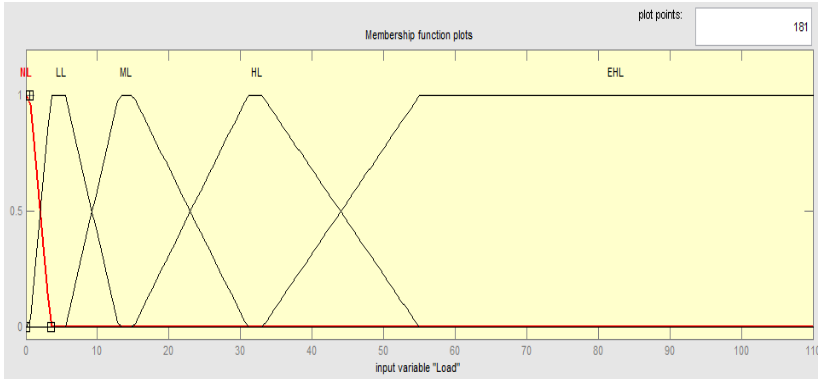

FIGURE 4: Membership function editor describing all membership functions for the input variable 'Load'.

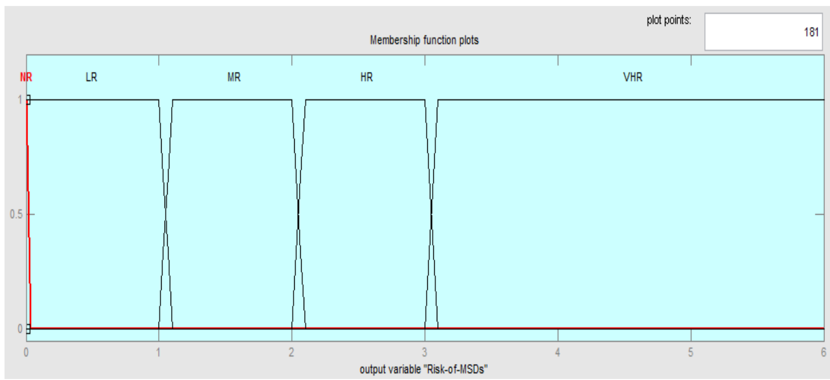

FIGURE 5: Membership Function Editor describing all membership functions for the input variable 'LBP-risk' .

Figure 6 and 7 are presentations of the surface viewers for plots of two variables which enables viewing the model as it varies over the ranges of its variables. The surface viewer examines the output surface of the fuzzy inference system for two inputs at a time. The two input variables assigned to the two input axes (X and Y) with the output variable on Z axis to display the result of calculation and the plot. The constant value associated with unspecified input is supplied in the reference input section.

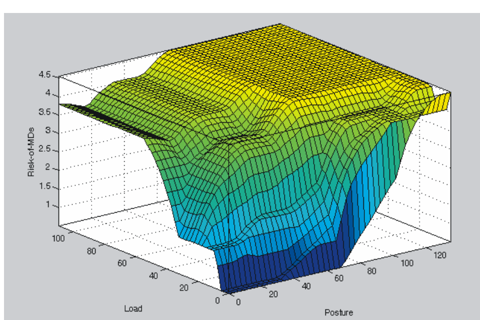

FIGURE 6: Surface found by mapping of the fuzzy based model (with variables posture, load and a reference point of 2.2 for frequency of lift).

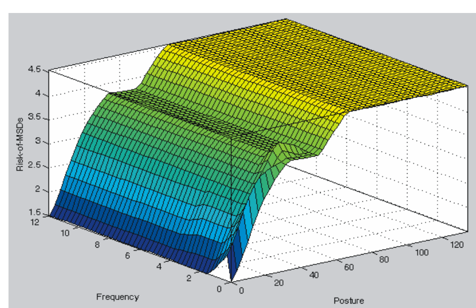

FIGURE 7: Surface found by mapping of the fuzzy based model (with variables frequency, posture and a reference point of 17.5kg for load).

3.1 Model Validation

In order to test the robustness of the model, twenty samples out of the antecedent variables recorded for all the workers were extracted (as presented in Table 6). The values range from LI<1 to LI>3. These model values were compared with the human expert calculated values using the human expert opinion which divided LI into five categories: LI=0 (No risk), LI=0-1(low risk), LI=1-2 (medium risk), LI= 2-3 (high risk) and LI= greater than 3 (Very high risk) [19].

Sample	Load (Kg)	Freq. (Lift/min)	Posture (Degree)	RWL	LI (Expert Value)	Model Value
1	24	1.3	35	6.8	3.53	3.57
2	24	2.1	55	5.74	4.18	3.74
3	24	1.1	45	5.3	4.53	3.57
4	2	1.9	40	4.06	0.49	0.76
5	8	3.2	0	7.89	1.01	1.28
6	10	3.8	0	7.31	1.37	1.52
7	24	1.5	10	11.1	2.16	2.55
8	24	2	45	6.09	3.94	3.57
9	28	1.9	10	11.47	2.44	2.48
10	28	8.8	30	5.49	5.1	3.64
11	26	2.1	35	7.84	3.32	3.65
12	6	5.0	30	2.23	2.69	2.33
13	11	0.5	30	6.82	1.61	1.8
14	12	0.8	50	6.37	1.89	1.87
15	28	2.6	50	6.04	4.64	3.67
16	2.5	0.3	40	7.54	0.33	0.57
17	7	0.1	65	7.09	0.99	1.0
18	15	1.3	60	5.15	2.92	2.34
19	24	2	25	7.56	3.17	3.31
20	22	1.8	30	5.44	4.04	3.27

TABLE 6: Operations studied, data recorded, expert calculated risk value and model risk values for twenty healthy male construction workers.

Figure 8 is a multiple line graph which records individual data values of human experts' calculated values and fuzzy model values as marks on the graph. The changes from point to point are visible. The major divergence of human experts' prediction from the model values were recorded in sample 10 where the human experts' calculated risk value was 5.1 while that of the model was

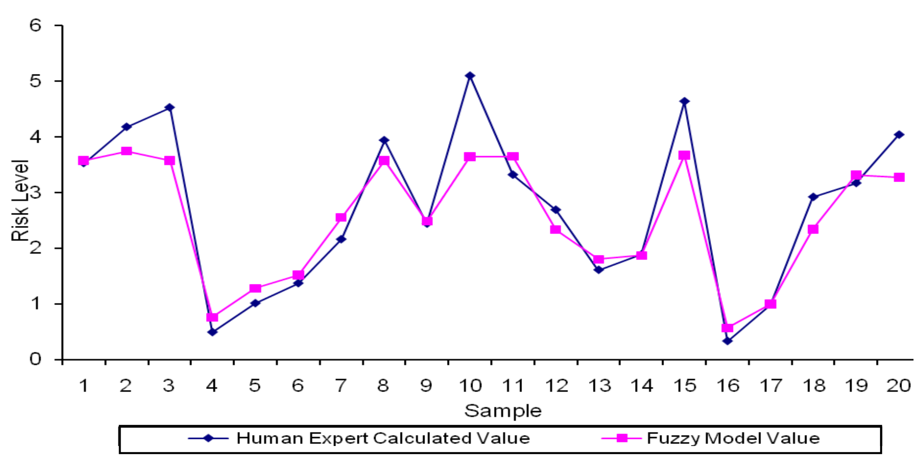

FIGURE 8: Comparing the calculated risk of human experts' value and the fuzzy based risk value.

3.64. The objective of the model is not to calculate the magnitude of lifting index value but to assess the risk involved in the task. The model predicted a very high risk (VHR) to any value greater than 3.0 which is also similar to the human expert's opinion which classified lifting index of 5.1 as VHR.

The Spearman correlation coefficient of the two sets of variables run on SPSS 16 was found to be 0.934. While comparing the means of the two sets using Independent Samples-T test at the confidence interval of 95%, the P- value for 2 tails was 0.637. The value indicates that there is not a statistically significant difference in the means of the two independent variables. Therefore the null hypothesis which stated that there is no significant difference between the calculated risks of human experts and the fuzzy model is accepted. The consequence of the validation however shows that there is a strong positive relationship and association between the two sets of variables.

In the fuzzy based LBP risk evaluation approach, one element can fit into two or more assort with different membership degree. The grade of membership expresses the degree of strength with which a particular element belongs to a fuzzy set, thus allowing a more realistic modeling of variable status and assists in determining the exact degree or level of a particular concept. Unlike the ordinary set theory which is governed by binary principles such that a variable either belongs to a set, which would indicate a membership value of 1, or it does not belong to the set and maintains a membership value of 0. The fuzzy approach also considered inherent uncertainties of the classification process, such as in the classification of a frequency of lift with 2.5 and another one with 2.6, who are relegated as MF (moderate frequency) and HF (high frequency) respectively. In this fuzzy approach, these frequency values (2.5 and 2.6) simultaneously fit into MF and HF with some membership.

The model provided good results when compared with the values obtained from human experts' calculations. It shows that the fuzzy sets theory can be a valuable tool that has encouraging results in bridging the gap between human-based and computer-based calculations of LBP risks among construction workers. It provides a model structure that requires the managers to make explicit decisions that will minimize lifting related risk among workers especially in construction jobs.

It is natural to expect that the fuzzy model could be improved with the introduction of new variables. Inclusion of variables such as personal factors (e.g anthropometry), indirect risk factors (e.g temperature, worker characteristics) is therefore becoming one of the future challenge and should be encouraged.

4. CONCLUSION

A fuzzy knowledge model was adopted to evaluate LBP risk from a set of three potential risk factors and have shown that the model can assist in assessing the risk in construction workers most especially for tasks that conform to the application of NIOSH lifting equations and provides a structure that enhances the administrators' denotative opinions. The outcome of the validation procedures shows that the adopted fuzzy model was capable of generating results of the same quality as the ones provided by human experts. Through the model, an improvement in the methods of efficiency in risk assessment was achieved. The model can help to reduce the risk associated with manual material lifting and to determine the effective means of deploying personnel in construction works.

5. REFERENCES

1. G.C. Phyllis. “Low Back Pain”. McKesson Health Solutions LLC. Internet: www.cumc.columbia.edu/student/health/pdf/I-L/Low%20Back%20Pain.pdf. [Nov. 19, 2012].

2. Q.A. Louw, L.D. Morris1 and K. Grimmer-Somers. “The Prevalence of low back pain in Africa: a systematic review”. BMC Musculoskeletal Disorders, vol. **8(**105), doi:10.1186/1471-2474-8-105, 2007.

3. J.W. Frymoyer, M.H. Pope, J.H Clements, D.G.Wilder, B. MacPherson, T. Ashikaga. “Risk factors in low-back pain”. Journal of Bone and Joint Surgery, vol. 65, pp. 213-218, 1983.

4. A. Linda, Merlino, C. John, D.A Rosecrance, M.Thomas, “Symptoms of Musculoskeletal Disorders among Apprentice Construction Workers”. Applied Occupational and Environmental Hygiene. College of Public Health, The University of Iowa, Iowa City, vol. 18(1) pp. 57–64, 2003.

5. European Agency for Safety and Health at Work (EASHW). “Building in Safety - Prevention of risks in construction in practice”. European Construction Safety Summit. Euskalduna Conference Centre, Bilbao, Spain, Issue 108, 2004.

6. N.K. Akinomayowa. “Reducing repetitive strain and back pain among bricklayers” In: Buckle, P. (Ed.). Musculoskeletal Disorders at Work. London. Taylor and Francis, vol. 1, pp. 189-193, 1987.

7. National Institute for Occupational Safety and Health (NIOSH). “Work Practices Guide for Manual Lifting (WPG)”, NIOSH Technical Report. U.S. Department of Health and Human Services, National Institute for Occupation, pp. 81-122, 1981.

8. H.K. Oude, B.M. Blatter, G.A. Geuskens, L.L. Koppes, P.M. Bongers. “Factors associated with the ability and willingness to continue working until the age of 65 in construction workers”. Int Arch Occup Environ Health.vol. 85(7), pp. 783-90, 2012.

9. F. Henk, M. Vander, K.S.Judith, H.W. Monique. “Musculoskeletal disorders among construction workers: a one-year follow-up study” BMC Musculoskeletal Disorders vol, 13 pp.196, 2012.

10. E.W. Bakker, A,P. Verhagen, T.E. Van, C. Lucas, B.W. Koes. “Spinal mechanical load as a risk factor for low back pain: a systematic review of prospective cohort studies”. Spine. vol. 34(8). E281-93. doi: 10.1097/BRS, 2009.

11. F. Lotters, A. Burdorf, J. Kuiper, H. Miedema, “Model for the work-relatedness of low-back pain”. Scand.J Work Environ Health. vol.29, pp. 431-40, 2003.

12. D.B. Chaffin, G.B. Anderson. “Occupational Biomechanics” New York, John Wiley and Sons. 1991.

13. B.R. Da-Costa, V.E. Ramos. “Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies”. American Journal of Industrial Medicine, vol. 53 (3), pp. 285-323, 2010.

14. Government of Western Australia Department of Commerce Code of Practice (GWADCCP). Manual Tasks. Internet: www.docep.wa.gov.au/worksafe/PDF/.../Code_manual_handling. Nov. 26, 2012 [Nov. 27, 2012].

15. S. Lenore, J.P. Azaroff, P.William, P. Elise, R. Rick, R. Cora. "Addressing work-related injuries and illness: a guide for primary care providers in Assachusetts". Massachusetts coalition for occupational safety and health (massCOSH). (617) 825-SAFE, 2004.

16. T. Sturmer, S. Luessenhoop, A. Neth, M. Soyka, W. Karmaus, R.Toussaint, T.R. Liebs, U. Rehder. "Construction work and low back disorder. Preliminary findings of the Hamburg construction worker study". Spine, vol. 22 (21), pp. 2558-2563, 1997.

17. Institution for Occupational Safety and Health (IOSH). "MusculoSkeletal Disorders". Internet: www.iosh.co.uk/books_and_resources/our_oh_toolkit/musculoskeletal_disorders.aspx. Sept. 5, 2012 2012, [Sept. 6, 2012].

18. National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS). "Back Pain". Internet: www.niams.nih.gov/health_info/Back_Pain/back_pain_ff.asp. Sept. 8, 2009, [July 2, 2011].

19. T.R. Waters, S.L. Baron, L.A. Piacitelli, V.P. Anderson, T. Skov, M. Haring-Sweeney. The revised NIOSH lifting equation. A cross-sectional epidemiologic study. Spine, vol. 24(4), pp.386-94, 1999.

20. S. Boda, P. Bhoyar, A.Garg. "Validation of Revised NIOSH Lifting Equation and 3D SSP Model to Predict Risk of Work-Related Low Back Pain". Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting – 2010, San Francisco, Sept. 27 – Oct. 1, 2010.

21. R. Michael "NIOSH lifting equations": Q & A. Internet: www.ergoweb.com/news/detail.cfm?id=566. May 2, 2012 [July, 14, 2012].

22. T.R. Waters, M.L. Lu, L.A. Piacitelli, D. Werren, J.A. Deddens. "Efficacy of the revised NIOSH lifting equation to predict risk of low back pain due to manual lifting: expanded cross-sectional analysis". J Occup Environ Med. vol. 53(9) pp. 1061-7, 2011.

23. R.H. Westgaard. "Work-related musculoskeletal complaints: some ergonomics challenges upon the start of a new century". Appl. Ergon. vol. 31 pp. 569-80, 2000.

24. S. Aman, B.D. Gupta, A. Sneh, "Minimizing MusculoSkeletal Disorders in Lathe Machine Workers". International Journal of Ergonomics, vol. 1(2) pp, 20, 2011.

25. L. Crumpton, P. McCauley-Bell, T. Soh, "Modeling overall level of fatigue using linguistic modeling and fuzzy set theory". Applied Ergonomics. 1997.

26. M. Abdullah, and H. Tahir, "Modeling for Uncertainty Assessment in Human Health Risk Quantification: A Fuzzy Based approach". International Environmental Modelling and Software Society (iEMSs). Fifth Biennial Meeting. David A. Swayne, Wanhong Yang, A. A. Voinov, A. Rizzoli, T. Filatova (Eds.) Ottawa, Canada. S.O. 05, 2011.

27. D.J. Fonseca, T.W. Merritt, G.P. Moynihan, "Fuzzy Set Theory for Cumulative Trauma Prediction. Department of Industrial Engineering, the University of Alabama, Tuscaloosa. Mathware & Soft Computing, vol 8, pp, 129-135. 2011.

28. M.P. Kevin. "Fuzzy Control". Department of Electrical Engineering The Ohio State University. Addison Wesley Longman, Inc., pp. 123, 1998.

29. L. A. Zadeh. "Probability measures and fuzzy events". Journal of Mathematical Analysis and Applications. vol. 23, pp. 421, 1968.

30. MathWorks. "Fuzzy logic toolbox user's guide (version 2)". Internet: www.mathworks.com/help/pdf_doc/fuzzy/fuzzy.pdf. July 2002. [Sept.12, 2011].

31. A. Bansal. "Trapezoidal Fuzzy Numbers (a,b,c,d): Arithmetic Behavior". International Journal of Physical and Mathematical Sciences, ISSN: 20101791, pp. 39-44, 2011.

32. J. S. Oguntoyinbo, O.O. Areola, M. Filani. "A Geography of Nigerian development" [2nd ed.] Heinemann Educational Books (Nig.) Ltd., Ibadan, Nigeria, pp. 45-70, 1983.

33. T. Waters, V. Putz-Anderson, A. Garg. "Application manual for the revised NIOSH lifting equation". Cincinnati, OH; DHHS (NIOSH) Publication no. 94-110, 1994.

34. S. Y. Ramjeet, P.S. Vijendra. "Modeling academic performance evaluation using soft computing techniques; a fuzzy logic approach". International Journal on Computer Science and Engineering (IJCSE), vol. 3(2), pp. 676-686, 2011.

35. T.R. Waters, V. Putz-Anderson, A. Garg, L.J. Fine. "Revised NIOSH equation for the design and evaluation of Manual lifting tasks". Ergonomics, vol. 36, pp. 749-776, 1993.

36. A. M. Genaidy, W. Karwowski, D. Christensen, C.Vogiatzis, N. Deraiseh, A. Prins. What is "heavy"? Ergonomics, vol. 41(4), pp. 420-32, 1998.

37. S. Sumathi and P. Surekha "Fuzzy Inference and Expert Systems" Taylor and Francis group, LLC, DOI: 10.1201/9781439809037-c7, pp 261–306, 2010

38. J. Yen, I.R. Langar. Fuzzy logic: intelligence, control and information. Upper Saddle River (NJ). Prentice – Hall, 1999.

Designing an Ergonomics-Based Public Wudu Place for Indonesian Population Using Posture Evaluation Index and Virtual Environment Method

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Abstract

This research studied about ergonomics aspect for designing public wudu place in virtual environment. Data collection is conducted with Vicon System and analyzed by Software Jack 6.1. The method of this research is Posture Evaluation Index (PEI) which integrates three methods: Low Back Analysis, Ovako Working Posture Analysis, and Rapid Upper Limb Assessment. The purpose of this study is to evaluate the design of public wudu place and determine the most ergonomics design based on the movement while doing wudu. As for the results, the recommendation for the valve height from floor is 115 cm, the height of feet holder is 30 cm, and the distance between the man and the valve is 35 cm.

Keywords: Public Wudu Place, Virtual Environment, Posture Evaluation Index, Motion Capture, Ergonomics

1. INTRODUCTION

Wudu is one of Islamic procedure for washing parts of the body using water for preparation of formal prayers (Salah). Phoenetically, wudu comes from “Al-Wadha’ah” which means cleanliness and brightness. Based on literature, wudu uses water for certain human parts (face, hands, forehead, ears, and legs) to eliminate things that prohibit someone to do Salah or other type of pray.

Every moslems do wudu 5 times per day. Therefore, for moslems who are outside their house, public wudu place are used more than private wudu place in their house. In Indonesia, public wudu place can be found in mosque, musholla (small mosque), school, mall, and other public places. The public wudu place is commonly seen in Indonesia because most of Indonesians are moslem, and they have to do wudu 5 times a day to do Salah. However, not every public wudu place is comfortable to use. The comfortable criteria are divided into several things: the position of human before doing wudu, during doing wudu, and after doing wudu.

Based on 40 participants' data, 23.33% of them stated that they have experienced some injuries when doing wudu, which consist of back pain and other musculoskeletal disorders. From those participants, 53% of them are over 40 years old, 27% of them are 20-40 years old, and 20% of them are below 20 years old.

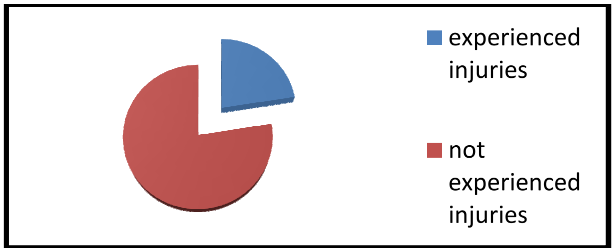

FIGURE 1: Percentage Chart of Participants who Experienced Musculoskeletal Problem during Wudu Activity.

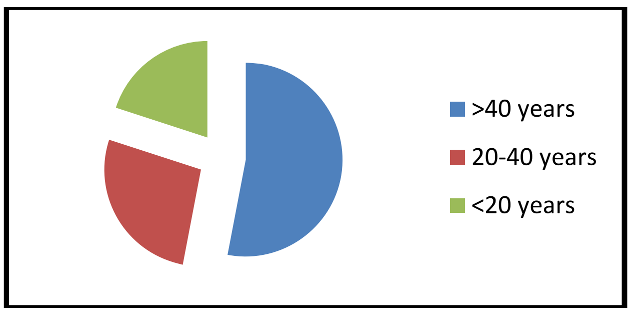

FIGURE 2: Percentage Chart of Participants' Age who Experienced Problem or Injury when Doing Wudu**.**

Injuries experienced by participants are waist pain (28.57%), being hit on feet (14.29%), fall or slip (42.85%), and complaint of limited space of wudu place (14.29%).

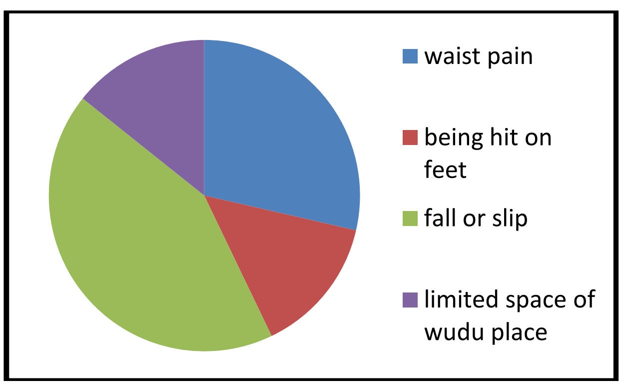

FIGURE 3: Percentage Diagram of Problems or Injuries when Doing Wudu.

There are two positions of doing wudu, which are: standing position and sitting position. In Indonesia, wudu place commonly facilitates people to do standing position. Wudu place with standing position has a different floor height, so people have to hold on a pillar for maintaining their balance. Therefore, there is a risk of tripping during doing wudu.

The position of valve in public wudu place sometimes is not compatible to Indonesian average height. Moreover, this will cause an uncomfortable situation when doing wudu, such as: when bend down, or when lifting one leg to be washed. Because of not all wudu place equipped with ceramics or anti-slip material, the risk of fall will be increased. The distance between one valve and the other valve also influenced comfortability when doing wudu.

Problems or injuries that take place when doing wudu are the background of this research. The purpose of this research is to design an ergonomics wudu place to reduce risks or injuries and increase comfortability. Repetitive action when doing wudu (5 times a day) will cause fatigue or WMSD (Work-related Musculoskeletal Disorders), which is related to other important parts of human body.

2. METHODS

In this research, wudu movement is modeled by software Jack 6.1, therefore analyzed by Posture Evaluation Index (PEI) method. Software Jack 6.1, is one of ergonomics software that can simulate how the human model (virtual human) that reside in virtual environments (virtual environment) can interact with objects and environments, as well as getting the right feedback from the manipulated object. Jack software development is particularly concerned to the creation of the human body model that most accurately compared with other digital human models ever. The condition of posture and the size of the virtual human anthropometric data can be adapted to real human beings who become the model of the simulation.

PEI method was developed by Francesco Caputo, Giuseppe Di Gironimo, and Adelaide Marzano from University of Naples Frederico II, Italy. The purpose of the use of this method is to perform the optimization of various configurations of feature geometry on a work station (F. Caputo, G. Di Gironimo, A. Marzano, 2006). This method is used to evaluate the posture of the human labor that is simulated in a virtual environment, especially using the Jack software, resulting in an index number that represents the level of comfort and health in the work.

PEI is an integration of the assessment results using the method of LBA, OWAS, and RULA, which are summarized into three-dimensional variables I1, I2, and I3. I1 shows the evaluation of the variable LBA score with a limit of compression strength to follow NIOSH (3400 N). I2 shows OWAS variable index is normalized by its maximum value of 4. While the index i3 is RULA normalized with its maximum score of 7. Because in this study have the upper body musculoskeletal injury risk greatest when viewed from walking posture using a backpack, then the variable is multiplied by the amplification factor I3 (mr) of 1.42.

Dimensional variables that define the PEI depend on the level of discomfort of working postures that was studied. The greater the level of discomfort a posture resulting greater score of the variable I1, I2, I3 and greater score of PEI. PEI score indicates the quality of a working posture, where the lower score among the various possible design configurations show better results. PEI score has a minimum value of 0.47 (condition in which the operator does not have the burden at all) and the maximum value of 3.42.

The first step is data collection. Data is collected from observation of public wudu place. Dimension of public wudu place, posture, and anthropometric data from participants are some types of data that are being collected. Some pictures and videos are also taken during the observation. There are 6 locations to collect data: office (in Baitul Ihsan Mosque that is located on Indonesian Bank area), school (in Ukhuwah Islamiyah Mosque University of Indonesia), public tourism place (in Istiqlal Mosque and At Tin Mosque that are located nearby National Monument and Taman Mini Indonesia Indah (TMII)), industrial place (in Istiqomah Mosque that is located nearby PT. Indonesia Epson Industry (IEI) in Cikarang), shopping center (in Alatief Mosque near Pasaraya Grande Blok M mall), and residences (in Azzikra Mosque near moslem residence Azzikra Sentul).

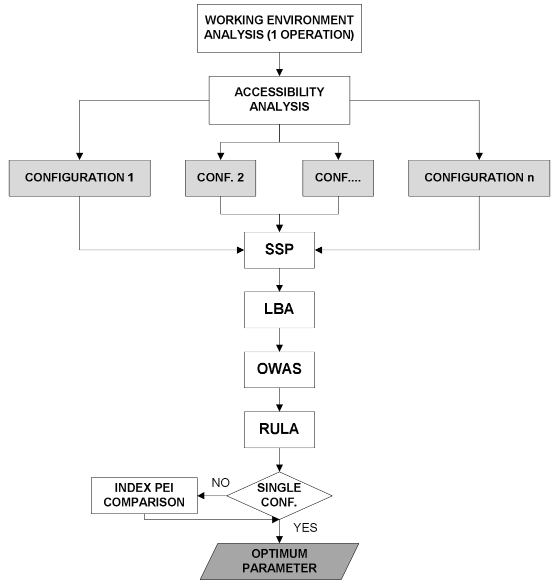

FIGURE 4: Steps to Implement PEI Method.

The second phase is to do data processing. In this phase, there are three processes: designing a public wudu place model using Google Sketchup 8 and UG NX, building virtual environment of public wudu place using software Jack, record the movement of model using Vicon Nexus as the motion capture software, and calculate PEI value using software Jack 6.1.

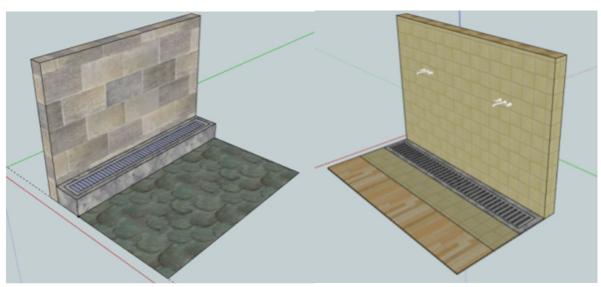

FIGURE 5: Wudu Place in Virtual Environment.

Virtual environment (VE) is a representation of the physical system that is generated by a computer. It allows users to interact with synthetic environments that have similarities with the real environment (R. Kalawsky, 1993). VE is an artificial environment created by computer and used in real-time (J. R. Wilson, D. J. Brown, S.V. Cobb, M. D. D'Cruz, and R. M. Eastgate, 1995). The form of this artificial environment can be a three-dimensional model that contains a collection of complex data. Users can manipulate the virtual human in the VE to interact with the environment and objects that exist in the virtual environment. Humans must be able to interact with virtual objects, environments, and get a response back from the object being manipulated.

Data collection is conducted using Vicon Nexus software that has a function to record body movements that will be analyzed (focused on extreme position wudu movement). The result of the recording then will be processed in software Jack 6.1 to analyze static strength prediction (SSP), lower back analysis (LBA), ovako working posture analysis system (OWAS), and rapid upper limb assessment (RULA) value from body posture. After those four values are obtained, the PEI value can be calculated.

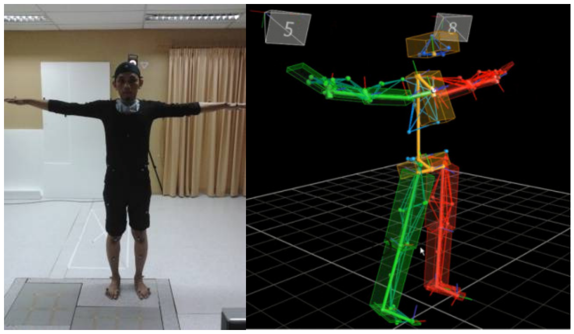

FIGURE 6: Motion Capture Process in Vicon Nexus Software.

The third phase is data analysis. Using software Jack 6.1, we can simulate how virtual human interacts to virtual environment to obtain a feedback. Software Jack development concerns about creating more accurate human model than other software. In software Jack, dimension of posture and anthropometric data really represent real human, so the result become more accurate.

3. RESULTS AND DISCUSSIONS

Designing a model with software Jack is conducted using 4 steps: 1) creating virtual environment based on actual wudu place model; 2) creating virtual human based on anthropometric data; 3) designing human model posture that represent actual wudu movement; 4) creating an animation system that represent actual wudu activity.

Early stage of data processing is determining PEI value from actual wudu place which is designed in virtual environment and virtual human using percentile P5, P50, and P95. Table 1 shows the result of PEI value for each actual wudu place.

There are 3 main factors that affect the design of best wudu place: 1) the height of valve from floor, 2) distance from human to valve, and 3) height of feet holder to assist feet washing in wudu. Those three factors will be simulated into three configurations: A (factor 1), B (factor 2), and C (factor 3). Based on the PEI score, the best PEI score for standing position wudu is the wudu place in school area, which is Ukhuwah Islamiyah Mosque.

TABLE 1: Results of PEI Value for Each Actual Wudu Place.

Wudu place	Gender	Percentile	PEI
Office	Man	95	2.37
		50	2.22
		5	1.51
	Woman	95	2.20
		50	2.16
		5	1.40
School	Man	95	1.77
		50	1.65
		5	1.51
	Woman	95	2.18
		50	2.15
		5	1.39
Public tourism place (1)	Man	95	2.38
		50	2.23
		5	1.51
	Woman	95	2.20

		50	2.17
		5	1.40
Public tourism place (2)	Man	95	2.51
		50	2.54
		5	2.08
	Woman	95	-
		50	-
		5	2.00
Industrial place	Man	95	2.55
		50	2.54
		5	2.10
	Woman	95	-
		50	-
		5	2.01
Shopping center	Man	95	2.58
		50	2.58
		5	2.13
	Woman	95	-
		50	-
		5	3.03
Residence	Man	95	1.60
		50	1.48
		5	1.41
	Woman	95	1.48
		50	1.40
		5	1.34

TABLE 2: The Results of PEI Score For Height of Valve (male).

Height of valve (cm)	Percentile	RULA	LBA	OWAS	PEI
85	95	4	2	1430	1.732
	50	4	2	1112	1.638
	5	3	2	895	1.372
90	95	3	2	1292	1.489
	50	3	2	996	1.402
	5	3	2	892	1.371
95	95	3	2	1045	1.416
	50	3	2	779	1.338
	5	3	2	629	1.294
100	95	3	1	887	1.119
	50	3	2	776	1.337
	5	3	2	610	1.288
105	95	3	1	818	1.099
	50	3	1	630	1.044
	5	3	1	507	1.008
110	95	3	1	661	1.053
	50	3	1	520	1.012

	5	3	1	464	0.995
115	95	1	1	666	0.649
	50	1	1	525	0.607
	5	1	1	467	0.59
120	95	1	1	668	0.649
	50	1	1	526	0.608
	5	1	1	516	0.605
125	95	1	1	672	0.651
	50	1	1	530	0.609
	5	1	1	517	0.605
130	95	1	1	674	0.651
	50	1	1	531	0.609
	5	1	1	518	0.605

Design of configuration A is based on the height of valve. In this configuration, there are 10 combinations of valve height from range 85 cm to 130 cm. based on table 2, the smallest PEI score is on 115 cm and 120 cm height. Moreover, PEI score of below 115 cm height is bigger than PEI score of above 120 cm height. Design of configuration B is based on the distance from human to valve. In this configuration, there are 6 combinations of distance from 30 cm to 55 cm.

TABLE 3: The Results of PEI Score For Distance of Valve (Male).

Distance from human to valve	Percentile	RULA	LBA	OWAS	PEI
30	95	3	1	668	1.055
	50	3	1	483	1.001
	5	3	1	423	0.983
35	95	4	1	686	1.263
	50	4	1	503	1.209
	5	3	1	433	0.986
40	95	4	1	711	1.271
	50	4	1	506	1.210
	5	4	1	444	1.192
45	95	4	1	719	1.273
	50	4	1	533	1.218
	5	4	1	521	1.215
50	95	3	2	722	1.321
	50	3	2	632	1.294
	5	3	1	605	1.037
55	95	4	1	862	1.315
	50	3	1	769	1.085
	5	3	1	718	1.070

From table 3, the smallest PEI score comes from the distance of 30 cm and 35 cm. On the other hand, PEI score of distance above 35 cm has bigger value for 3 percentile. Furthermore, PEI score of distance 55 cm for percentile 50 and 95 experience a huge decrease, but not followed by percentile 5. This is because percentile 50 and 95 do not need the extreme bending position to get the water, which percentile 5 has to do the bending. Moreover, configuration C has 3 types of foot holder height: 30, 35, and 40 cm. C1 symbolizes 30 cm, C2 for 35 cm, and C3 for 40 cm.

TABLE 4: PEI Score for Configuration C.1.

Gender	Percentile	RULA	LBA	OWAS	PEI
Man	95	3	2082	2	1.76
	50	6	1634	2	2.23
	5	3	1292	2	1.51
Woman	95	6	1548	2	2.20
	50	6	1194	2	2.09
	5	3	919	2	1.40

TABLE 5: PEI Score for Configuration C.2.

Gender	Percentile	RULA	LBA	OWAS	PEI
Man	95	6	1541	2	2.20
	50	6	2102	2	2.37
	5	6	1576	2	2.21
Woman	95	3	1238	2	1.50
	50	6	1550	2	2.20
	5	6	1245	2	2.11

TABLE 6: PEI Score for Configuration C.3.

Gender	Percentile	RULA	LBA	OWAS	PEI
Man	95	6	2209	4	2.91
	50	6	1954	2	2.33
	5	3	1287	2	1.51
Woman	95	6	1688	4	2.74
	50	6	1254	2	2.11
	5	3	1023	2	1.43

PEI score that is obtained from actual condition analysis and configuration is used as standard to determine ergonomics optimization of an operation in one workstation. This table below illustrates the cumulative of PEI score from simulation of standing position wudu place.

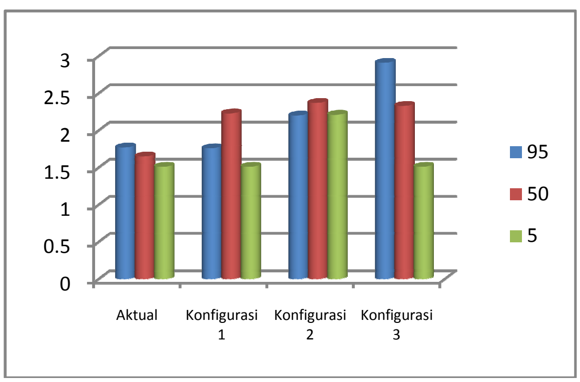

FIGURE 7: Comparison of PEI Score (Male).

The graph in figure 7 shows all comparison of PEI score for every configuration using male virtual man. That graph shows that PEI score for each configuration has no significant change, unless for configuration 3 which has bigger PEI score. It means that configuration 3 is the worst. However, actual design has better PEI score than the others.

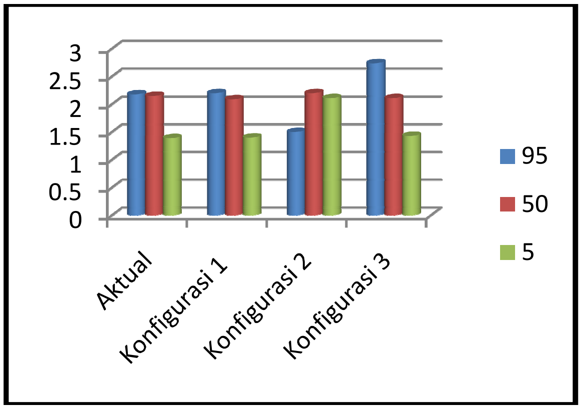

FIGURE 8: Comparison of PEI Score (Female).

Figure 8 shows the result of PEI score comparison for each configuration using female virtual man. The result is indifferent with figure 6, that there is no significant change of PEI score, and configuration 3 has the worst PEI value. On the other hand, PEI score for sitting position can be seen in table 7, as the comparison for standing position.

TABLE 7: PEI Score for Sitting Position of Wudu Place.

Gender	Percentile	RULA	LBA	OWAS	PEI
Man	95	3	1564	2	1.60
	50	3	1204	2	1.48
	5	3	972	2	1.41
Woman	95	3	1199	2	1.48
	50	3	937	2	1.40
	5	3	741	2	1.34

Based on table 7, PEI score for wudu place in sitting position is better than standing position. It is because of the posture when doing wudu. Smaller load in back is experienced during sitting than standing.

Based on this research, best configuration for wudu place is obtained using Virtual Environment approach. Previous research supports ergonomics researches that are conducted using Virtual Environment, some of them used to design products (Jung et al., 2009 and Patel et al., 2005), workstation (Cimino et al., 2009), and participatory design in workplace (Wilson, 1999 and Sundin et al., 2003). Design of public wudu place in Indonesia will be beneficial to design public wudu place for all over the world, especially in Moslem country, because wudu is a repetitive activity for moslems. There is not much previous research in designing wudu place, especially in Indonesia, therefore it is a must to do further research of this study for designing wudu place in other country other than Indonesia. Further research using more reliable method can also be conducted.

4. CONCLUSION

From configuration analysis, there are some conclusions that can be made: (1) sitting position is better for doing wudu than standing position, (2) factors affecting PEI score are height of feet holder and valve height, (3) The optimal height of valve is 115-120 cm, (4) the optimal height of feet holder is between 35-40 cm, and (5) the optimal distance of valve to human is between 30-35 cm.

5. REFERENCES

1. Bridger, R.S. (2003). *Introduction To Ergonomics. London*: Taylor & Francis.

2. Caputo, F., Gironimo, G.D., Marzano, A. ”Ergonomic Optimization of A Manufacturing System Work Cell in a Virtual Environment”, 21-27.

3. Cimino, A., Longo, F., and Mirabelli, G. A Multimeasure-based Methodology for the Ergonomic Effective Design of Manufacturing System Workstations. *International Journal of Industrial Ergonomics 39 (2009) pp. 447-455.*

4. Helander, M. (2006). A Guide To Human Factors And Ergonomics (2nd ed.) London: Taylor & Francis.

5. Jung, K., Kwon, O., You, H. Development of a Digital Human Model Generation Method Ergonomic Design in Virtual Environment. *International Journal of Industrial Ergonomics 39 (2009) pp. 744–748.*

6. Neville, Stanton., Alan, H., Karel, B., Eduardo, S., and Hal, H.(2005). Handbook of Human Factors and Ergonomics Methods. Washington, D.C.: CRC PRESS.

7. Patel, H., Stefani, O., Sharples, S., Hoffmann, H., Karaseitanidis, I., and Amditis, A. Human Centered Design of 3D Interaction Devices to Control Virtual Environments. *International Journal of Human-Computer Studies 64 (2006) pp. 207–220.*

8. Sanders, M.J. (2004). Ergonomics and The Management of Musculoskeletal Disorders. Second Edition. Amsterdam: Elsevier.

9. Sundin, A., Christmansson, M., and Larsson, M. A Different Perspective in Participatory Ergonomics in Product Development Improves Assembly Work in the Automation Industry. *International Journal of Industrial Ergonomics 33 (2004) pp. 1-14.*

10. Wilson, J. R. Virtual Environments Application and Applied Ergonomics. *Applied Ergonomics 30 (1999) pp. 3-9.*

Evaluation of Students' Working Postures in School Workshop

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Abstract

Awkward postures are one of the major causes of musculoskeletal problems to be prevented at an early stage. Tackling this problem at the initial stage in schools would be of great importance. Tasks should be designed to avoid strain and damage to any part of the body such as the tendons, muscles, ligaments, and especially the back. Musculoskeletal disorder and back pain problems in adults was partly contributed by having such symptoms in their childhood. It is important to understand the symptoms of low back pain in children and design early interventions to prevent chronic symptoms that they may experience when they are adults. Musculoskeletal disorder and back pain problems in children and adolescent may give great implications in future workforce. The objective of this study was to compare working postures among students 13 to 15 years old while performing tasks in school workshop, therefore problems of musculoskeletal pain among students can be identified. Ergonomic assessments used for this study were the RULA and REBA methods. This cross-sectional study was conducted at a secondary school in Malaysia. Ninety-three working postures were evaluated to find out the posture risk level. Analysis result showed the average score are 4.87 and 5.87 for RULA and REBA methods respectively, which indicate medium risk and need for further action. The results also informed that 13-year old students had higher scores for both methods. Comparison using Kruskal-Wallis rank test showed there were significant differences among age groups for both scores and action levels. 13-year old students have the highest mean rank indicating bigger potential risks of awkward postures. In conclusion, both methods proved the workstation is mismatched for students' body size especially for younger students. An ergonomic intervention is needed to improve students' working posture, work performance and level of comfort.

Keywords: School Workshop, RULA, REBA, Working Posture, Student.

1. INTRODUCTION

Safety in school programs in Malaysia was started in 2002 to improve safety awareness for schoolchildren, teachers, parents and general population [3, 13]. Unfortunately, ergonomics issues among students are not documented widely compared to other safety issues such as air and water pollution, sports activities and other hazards in school.

In recent years, students in Malaysia has been suffering from musculoskeletal disorder symptoms because of furniture mismatch in schools [1, 27]. According to A. Sachdeva et al [28], musculoskeletal disorder is a condition which a part of musculoskeletal system get traumatized over a period of time. Mohd Azuan et al [17] also indicated that school-related factors such as backpack and school furniture had been identified as a common risk of musculoskeletal disorder and back pain. However, there is still lacking in ergonomic intervention in school environment and facilities. S. Murphy et al [17] revealed that specifications of school furniture have the highest prevalence of inducing pain. Conventional workstations that are currently used in school are often described as incompatible for students.

It is agreed by many researchers that school furniture is one of the factors that may contribute to musculoskeletal pain (MP) among schoolchildren [6, 7, 17, 27]. Researchers claimed that ergonomically designed school furniture might reduce the risks of early symptoms of musculoskeletal disorders [8, 14, 25]. Besides ergonomic furniture in classrooms, ergonomic factors in other locations such as science laboratories and workshops should also be taken into consideration for designing ergonomic furniture. Children and adolescents should've been introduced to ergonomic and correct posture habits for them to take care of themselves, especially their back [2, 9].

Secondary school students spend at least five hours in school and their activities circulates in classrooms, laboratories, workshops, and sports lessons as part of their learning processes. School furniture gives a high impact on their posture habit. They can develop musculoskeletal disorder and back pain if mismatch occurs [4, 26]. Bad posture was among the risk factors associated with discomfort while doing these activities. Pain is usually related with static posture, sitting arrangement and loads carried. Students tend to show a variety of postures while seated and performing tasks regardless of the furniture [15]. Different postures may contribute to different sites of discomfort. On the other hand, they are prone to adopt flexed postures when working at the desk. To conclude, it is important to investigate all relevant risk factors in order to identify the postural stress among students [22].

2. METHODOLOGY

This study was done at a secondary school in Klang district, Selangor. Subjects were among students' ages 13 to 15 years old. All subjects were in voluntary basis and have been notified about the purpose of the study. All of them have had the experience of using the school workshop's workstation for at least five hours to complete the woodworking project. Activities for evaluation were materials cutting and assembly tasks. These activities were recorded and ninety-three working postures were selected to calculate the scores.

Figures 1 and 2 show how assembly and cutting tasks were performed in a school workshop. Students use the workshop to complete a woodworking project for one hour and 45 minutes per week. Besides coursework project, some of them also use the workshop as classroom for living skills subject. All tasks were observed by a trained researcher. Task specifications was informed to ensure the completion of the assessment which are RULA and REBA methods.

Rapid Upper Limb Assessment (RULA) is a method to identify postural stress of upper limbs that was originally developed by McAtamney & Corlett [16]. The risk is calculated into scores and classified into four action levels. A RULA sheet consists of body posture diagrams and scoring tables. Based on the RULA method, the human body is divided into two parts, which are part A for Arm and Wrist analysis while part B for Neck, Trunk and Leg Analysis. A scoring system is used to assign scores at every step, depending on the body position, with the higher scores for more awkward postures. RULA method is widely used in ergonomic field.

Hignett & McAtamney [10] developed the Rapid Entire Body Assessment (REBA) method. Unlike RULA method that focused on sedentary tasks, REBA method assesses the whole body. The risk calculates into the score with five action levels. A REBA sheet consists of body posture diagrams and three scoring tables. The human body is divided into two parts, which are part A for Neck, Trunk and Leg analysis while part B is for Arm and Wrist Analysis. A scoring system is used to assign scores at every step. The process depends on the specific body position, showing higher scores for more awkward postures. Both methods have categorized action levels to indicate action requirement. Table 1 and 2 show the action levels for each score.

FIGURE 1: Cutting Task.

FIGURE 2: Assembly Task.

Statistical analysis was conducted using SPSS Version 17.0 software. A Kruskal-Wallis test was done to justify significant differences among students' age. A Pearson correlation test was also done to compare the relationship of the risk assessment scores between applied methods. *P* value < 0.05 was considered statistically significant.

Score	Indication
1 and 2	Acceptable posture
3 and 4	Changes are recommended
5 and 6	Changes are soon required
7	Changes are immediately required

TABLE 1: RULA: Score and Indication.

Score	Indication	Action
1	None	Not necessary
2 to 3	Low	May be necessary
4 to 7	Medium	It is necessary
8 to 10	High	Very necessary
11 to 15	Very high	It is urgent

TABLE 2: REBA: Score and Indication.

3. RESULTS

The analysis results reveal that average posture score for RULA method is 4.87 which mean deeper investigation is needed and changes may be required while the score using REBA method is 5.87 which indicate medium risk, and that action is necessary. Comparison among age groups showed that 13 year-old students have the highest risk in posture scores. Table 3 explains the scores obtained from both methods. The table showed that students age 13 years old have the highest average RULA and REBA posture score by 5.31, which means changes are required soon and 6.66, which categorized under medium risk level, respectively. This result shows that the current workstation is more suitable for older students that are more likely to have bigger and taller body sizes.

Age	N	RULA (Average)	REBA (Average)
13	29	5.31	6.66
14	36	4.81	5.72
15	28	4.50	5.25
Average score		4.87	5.88

TABLE 3: Average Scores Among Age Groups.

According to RULA method results, 48.38% posture scores indicate changes might be required, 39.78% required changes soon and 11.82% needed changes immediately. As for the REBA method analysis 12.9%, 77.41% and 9.68% postures were classified under high risk, medium risk and low risk respectively.

Age	N	RULA (%)		
		Changes are recommended	Changes are soon required	Changes are immediately required
13	29	31	55	14
14	36	50	39	11
15	28	64	25	11

TABLE 4: Percentage of Action Levels of RULA Outputs from 93 Posture Analyses.

Age	N	REBA (%)		
		Low risk	Medium risk	High risk
13	29	7	65	28
14	36	6	88	6
15	28	18	75	7

TABLE 5: Percentage of Action Levels of REBA Outputs from 93 Posture Analyses.

The Kruskal-Wallis rank test in table 6 showed that RULA and REBA scores have significant differences among students' age groups. Further analysis was done and the results in table 7 showed significant differences between RULA and REBA action levels among different age groups.

Age	N	Mean rank	
		RULA scores	REBA scores
13	29	56.84	59.16
14	36	45.63	44.88
15	28	38.57	37.14
P value		0.027	0.006
95% CI		0.000, 0.051	0.000, 0.032

TABLE 6: Kruskal-Wallis Test for RULA and REBA Scores Among Age Groups.

Age	N	Mean rank	
		RULA scores	REBA scores
13	29	54.59	54.29
14	36	46.17	45.58
15	28	40.21	41.27
P value		0.083	0.038
95% CI		0.053, 0.184	0.008, 0.100

TABLE 7: Kruskal-Wallis Test for RULA and REBA Action Levels Among Age Groups.

The Pearson correlation test was conducted between RULA and REBA scores and action levels. Results in table 8 and 9 showed a significant correlation for both methods. The correlation coefficients for scores and action levels between RULA and REBA methods were r = 0.480 and r = 0.305, respectively.

		RULA	REBA
RULA	Pearson correlation	1	0.480*
	Sig. (2-tailed)		0.000
	N	93	93
REBA	Pearson correlation	0.480*	1
	Sig. (2-tailed)	0.000	
	N	93	93

*Correlation is significant at the 0.01 level (2-tailed)

TABLE 8: Correlation Test between RULA and REBA Scores.

		RULA	REBA
RULA	Pearson correlation	1	0.305*
	Sig. (2-tailed)		0.003
	N	93	93
REBA	Pearson correlation	0.305*	1
	Sig. (2-tailed)	0.003	
	N	93	93

*Correlation is significant at the 0.01 level (2-tailed)

TABLE 9: Correlation Test Between RULA and REBA Action Levels.

4. DISCUSSION

The main purpose of the study was to compare working postures of 13–15 years old students in school workshop. An additional objective was to relate Rapid Upper Limb Assessment (RULA) method to Rapid Entire Body Assessment (REBA) method as evaluation tools for students' working postures.

The results of percentages and statistical analyses indicated that younger students' aged 13 year old faced higher potential risk of musculoskeletal pain compared to older students aged 14 and 15 years old. The 13 year old students have higher risk level in which deeper investigations were required to improve students' working postures. The results of both methods showed that younger students which generally have smaller body sizes have more difficulties while using the workstation. In a study of designing classroom furniture, the authors indicated that younger students have smaller body sizes as compared to older students. Therefore, furniture design criteria should be provided for three age groups for secondary schools which are 10-11 years, 12-13 years and 14 – 15 years old [12].

In this study, it was suggested that most likely the current workshop furniture is more suitable for bigger sized students. The school's management might have equipped the school workshop with adult size furniture that is mismatched for growing adolescents. The size of school workstation should be based on students' stature, rather than any other body segments [19]. In addition, Kruskal-Wallis test showed significant differences among age groups in both assessment methods for scores and action levels. Thus, it can be justified that each age group faced different risk levels while performing tasks in school workshop. 13-year old students having the highest mean rank means they tend to have bigger potential risk of awkward postures. An ergonomically designed workbench and stool should be provided to improve the working conditions of the students and reduce the potential risk of MSD.

The results of the correlation test between RULA and REBA scores showed that they were highly correlated [14]. This result agreed with a study conducted by Nasl Saraji et al [14], which indicated that final scores and action level of RULA and REBA methods were correlated to evaluate WMSDs risk factor and poor working postures in workplaces. Therefore, it is possible to interchangeably apply both methods to assess postural risk in appropriate working condition. Furthermore, RULA and REBA methods were recommended for evaluation in similar environments.

5. CONCLUSION

Based on the findings, there are significant differences among students in three different ages. The 13 year old students group faced the highest WMSD risk while using the school workshop. School furniture and workstations should suit the students' body sizes and anthropometric body dimensions [3, 5, 11, 12]. A study by Murphy et al [13] indicated that school furniture characteristics have the highest prevalence of relationship to pain among schoolchildren.

In order to improve working posture and reduce factors that are associated with back pain, participatory ergonomic programs should be introduced in schools in terms of posture training or furniture modification. Considering children today are adults of tomorrow, this makes ergonomic education essential in their early stage of life to develop a good posture habit and maintain their physical health [7, 8].

Further research on the ergonomics potential of students' working postures will investigate the effects of ergonomics interventions of ergonomically designed workstation to decrease the MSD and improve their work performance. In order to meet these positive results, the measures which are reviewed in this paper can be applied to evaluate ergonomics conditions of the workstation.

6. REFERENCES

1. Ahmad Nazif Noor Kamar, S. Ezrin Hani, C.K. Lee, and I. Ahmad Rasdan. "A study on the suitability of science laboratory furniture in Malaysian secondary school," presented at the Asia Pacific Symposium on Advancements in Ergonomics and Safety, Perlis, 2011.

2. C. Bennett and D. Tien. "Ergonomics for Children and Educational Environments –Around the World," presented at the International Ergonomics Association, Seoul, South Korea, 2003.

3. P. Boon, "Occupational safety awareness in schools," Borneo Post (April 22, 2011).

4. J. M. Brewer, K. G. Davis, K. K. Dunning, and P. A. Succop. "Does ergonomic mismatch at school impact pain in school children?" Work, vol. 34(4), pp. 455-464, 2009.

5. I. Castellucci, M. A. Gonçalves and P. M. Arezes. "Ergonomic Design of School Furniture: Challenges for the Portuguese Schools," presented at the Applied Human Factors and Ergonomics Miami, Florida, USA, 2010.

6. C. Parcells, M. Stommel, and R. P. Hubbard. "Mismatch of Classroom Furniture and Student Body Dimensions," Journal of Adolescent Health, vol. 24, pp. 265–273, 1999.

7. H.I. Castellucci, P.M. Arezes, and C.A. Viviani. “Mismatch between classroom furniture and anthropometric measures in Chilean schools,” Applied Ergonomics, vol. 41, pp. 563–568. 2010.

8. O. Hänninen and R. Koskelo. “Adjustable tables and chairs correct posture and lower muscle tension and pain in high school students,” presented at the Proceedings of the XVth Triennial Congress of the International Ergonomics Association, Seoul, South Korea, 2003.

9. E. Heyman and H. Dekel. “Ergonomics for children: An educational program for physical education students,” presented at the IEA World Congress on Ergonomics, Maastricht, Netherlands, 2006.

10. S. Hignett and L. McAtamney. “Rapid Entire Body Assessment (REBA),” Applied Ergonomics, vol. 31, pp. 201-205, 2000.

11. C. Kemper, and R. Tholen, “Pain in the back: Avoiding back pain in children and teenagers”. Internet: http://www.painintheback.eu/LiteratureReview-Painintheback.pdf, 2004.

12. G. C. Khaspuri, S. K. Sau and P. C. Dhara. “Anthropometric Consideration for Designing Class Room Furniture in Rural Schools,” Journal of Human Ecology, vol. 22(3), pp. 235-244. 2007.

13. C. B. Kim, “Making schools safe for work, study and play,” New Straits Times (November 17, 2011).

14. R. Koskelo, K. Vuorikari and O. H. Hanninen, “Sitting and standing postures are corrected by adjustable furniture with lowered muscle tension in high-school students,” Ergonomics, vol. 50(10), pp. 1643–1656, 2007.

15. B. Maslen and L. Straker, “A comparison of posture and muscle activity means and variation amongst young children, older children and young adults whilst working with computers,” Work, vol. 32, pp. 311–320, 2009.

16. L. McAtamney and E. N. Corlett, “RULA: A survey method for the investigation of work-related upper limb disorders,” Applied Ergonomics, vol. 19(2), pp. 91-99, 1993.

17. K. Mohd Azuan, H. Zailina, B. M. T. Shamsul, M. A. Nurul Asyiqin, M. N. Mohd Azhar and I. Syazwan Aizat, ”Neck, shoulder, upper back and lower back pain and associated risk factors among primary school children in Malaysia,” Applied Sciences, vol. 10(5), pp. 431-435, 2010.

18. M. Mokdad and M. Al-Ansari, “Anthropometrics for the design of Bahraini school furniture,” International Journal of Industrial Ergonomics, vol. 39, pp. 728–735, 2009.

19. J. Molenbroek, K. R. Ymt and S. Cj, “Revision of the design of a standard for the dimensions of school furniture,” Ergonomics, vol. 46(7), pp. 681-694, 2003.

20. R. Motmans, “Evaluation of three types of school furniture according to prEN 1729” presented at the IEA World Congress on Ergonomics, Maastricht, Netherlands, 2006.

21. S. Murphy, P. Buckle and D. Stubbs, “Back Pain Amongst Schoolchildren and Associated Risk Factors,” presented at the International Ergonomics Association XVth Triennial Congress, Seoul, Korea. 2003.

22. S. Murphy, P. Buckle and D. Stubbs, “Classroom posture and self-reported back and neck pain in schoolchildren,” Applied Ergonomics, vol. 35, pp. 113–120, 2004.

23. J. Nasl Saraji, M. Ghaffari and S. J. Shahtaheri, “Survey of Correlation between Two Evaluation Method of Work Related Musculoskeletal Disorders Risk Factors REBA & RULA,” Iran Occupational Health Journal, vol. 3(2), pp. 5-10, 2006.

24. L. O’Sullivan, T. Gallwey, G. Zülch, H. Jagdev and P. Stock. “Workplace Injury Risk Prediction and Risk Reduction Tools for Electronics Assembly Work,” Integrating Human Aspects in Production Management, vol. 160, pp. 173-183, 2005.

25. S. A. Oyewole, J. M. Haight and A. Freivalds, “The ergonomic design of classroom furniture/computer work station for first graders in the elementary school,” International Journal of Industrial Ergonomics, vol. 40, pp. 437-447, 2010.

26. C. S. Savanur, C. R. Altekar and A. De, “Lack of conformity between Indian classroom furniture and student dimensions: Proposed future seat/table dimensions,” Ergonomics, vol. 50(10), pp. 1612–1625, 2007.

27. Syazwan Aizat Ismail, Shamsul Bahri Mohd Tamrin and Zailina Hashim, “The Association between Ergonomic Risk Factors, RULA Score, and Musculoskeletal Pain among School Children: A Preliminary Result,” Global Journal of Health Science, vol. 1(2), pp. 73-84, 2009.

28. A. Sachdeva, B. D. Gupta and S. Anand, “Minimizing Musculoskeletal Disorders in Lathe Machine Workers,” International Journal of Ergonomics (IJEG), vol. 1(2), pp. 20-28, 2011.

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