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.

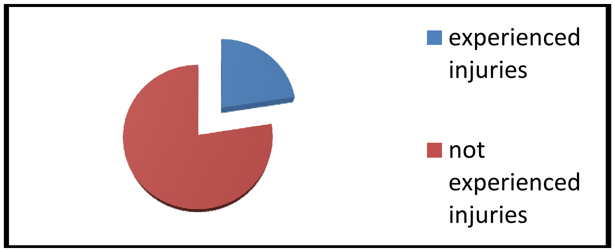

FIGURE 1: Percentage Chart of Participants who Experienced Musculoskeletal Problem during Wudu Activity.

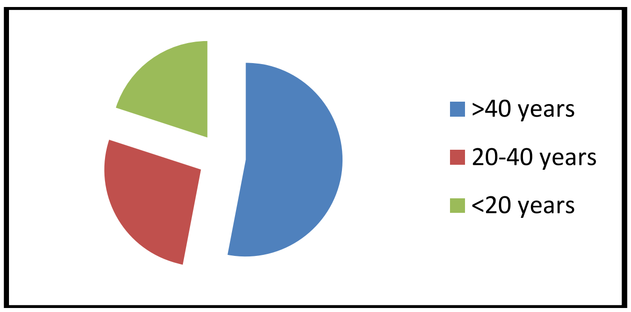

FIGURE 2: Percentage Chart of Participants' Age who Experienced Problem or Injury when Doing Wudu**.**

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%).

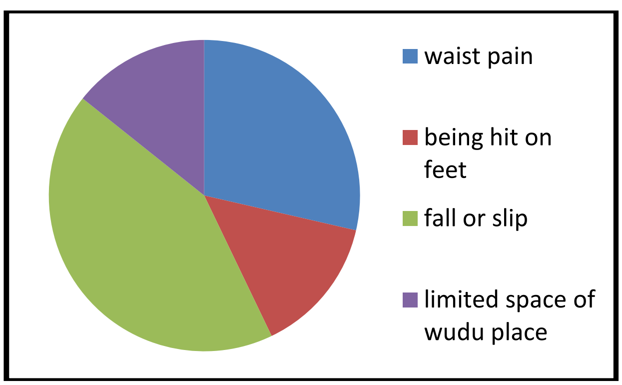

FIGURE 3: Percentage Diagram of Problems or Injuries when Doing Wudu.

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).

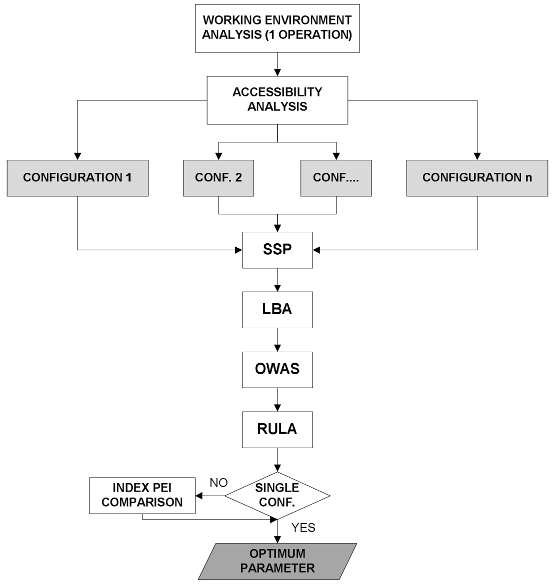

FIGURE 4: Steps to Implement PEI Method.

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.

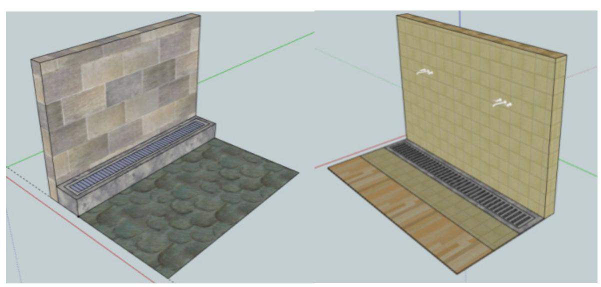

FIGURE 5: Wudu Place in Virtual Environment.

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.

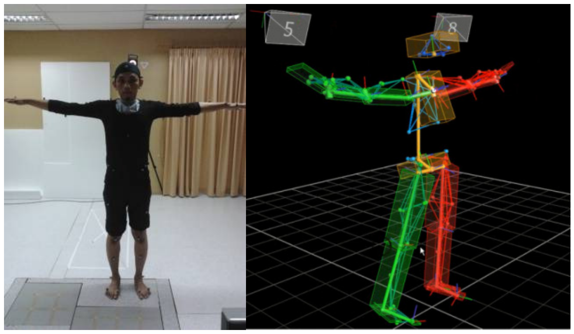

FIGURE 6: Motion Capture Process in Vicon Nexus Software.

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.

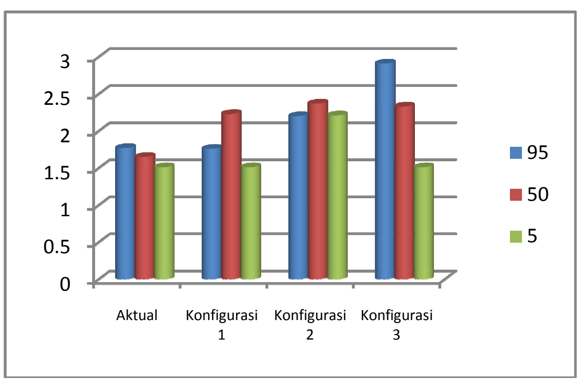

FIGURE 7: Comparison of PEI Score (Male).

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.

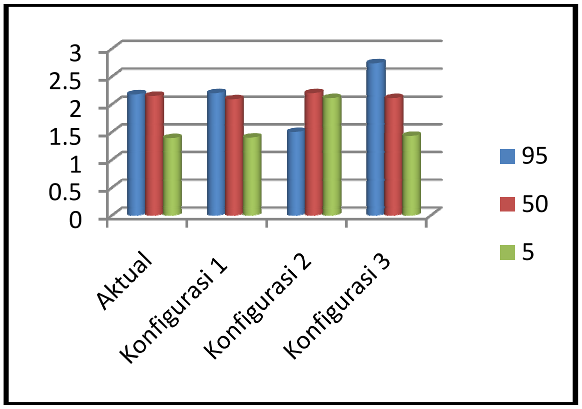

FIGURE 8: Comparison of PEI Score (Female).

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.

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