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Ergonomic Improvement of Drinking Water Dispenser for Indonesian People Using Rapid Upper Limb Assessment Method

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ABSTRACT

The existing water dispenser has been established in Indonesia for years which has various water tap designs and height levels as well. Unfortunately, the existing water tap design and height level have suited only for certain people with a height of less than 167 cm and therefore other taller people experienced bending posture when operating it. Furthermore, the water tap valve which required both hands to operate has made another effort to fill into the water media. Several research and methodologies have been proposed regarding water tap such as how to avoid water spills using the TRIZ method and how to enhance the smart dispenser through the Internet of Time. None of it discovered how to enhance its ergonomic aspect. However, to achieve improve the ergonomic level, several experiments and measurements have been performed in this research using Rapid Upper Limb Assessment (RULA) method, to generate a recommendation for ergonomic water dispensers.

Keywords: Ergonomic, Water Dispenser, Water Tap Valve, RULA.

1. INTRODUCTION

Human body requires water for the active and healthy life. Water requirements can vary depends on physical activity, age groups, body weight, climate, and diet (energy intake). According to Irianto (2017), water is the biggest component of human body which contribute 60% - 70% of body weight and therefore water is needed especially during sport activity or other heavy activity. A human requires 2.5 liter of water or equal to eight glass on daily basis (Asmadi et all, 2011). The awareness to drink at proper volume of water has become common recently by keeping it into water dispenser or other drinking media.

Water dispenser has been established in Indonesia for years. It has various water tap valve design and height level. To operate water tap valve, it has to be press or push by either single or both hands. Current water tap height level varies from 77 cm to 81 cm. Unfortunately particular users have experienced uncomfortable (bending) posture when tapping down the water from a dispenser, as shown in the following figure.

Figure 1 Body Posture during Water Dispenser Operation

A new standard and measurement need to be carried out to recommend more ergonomic posture during operate a dispenser. Several research and methodologies have been performed regarding to water tap such as how to avoid water spill using TRIZ method and how to enhance a smart water dispenser using Internet of Things, but none studied on how to improve ergonomic aspect of water dispenser.

Following to mentioned situation above, this research offered an improvement from ergonomic aspect of a water dispenser design using Rapid Upper Limb Assessment (RULA) method. The respondent data has randomly selected from respected adult users in Jakarta , Indonesia. User's habit in using water dispenser has been documented, measured and analyzed to recommend proposed improvement. Mc Attamney and Corlett (1993) proved that RULA method can investigate for work related upper limb disorders.

This paper addresses the un-comfort (bending) body posture using RULA method. The rest of this paper is organized as follows : first, a brief description of water dispenser is provided. Then, user's measurement and analysis are described, followed by recommended water dispenser design to improve ergonomic level. Finally, the paper is concluded.

2. LITERATURE SURVEY

2.1. The Rapid Upper Limb Assessment

Dr Lynn McAtamney and Professor E. Nigel Corlett developed the Rapid Upper Limb Assessment (RULA) method as a postural targeting method for estimating the risks of work-related upper limb disorders. A RULA assessment gives a quick and systematic assessment of the postural risks to a worker. The analysis can be accomplished before and after an intervention. This is to demonstrate that the intervention has worked to lower the risk of injury.

RULA method uses diagram or picture of body posture and three tables to evaluate risk factors. McPhee (1987) stated that risk factor for external loads factors are quantity of motion, static muscular work, force, working posture and restless working time. The stepping assessment and scoring sheet are shown in the following figure.

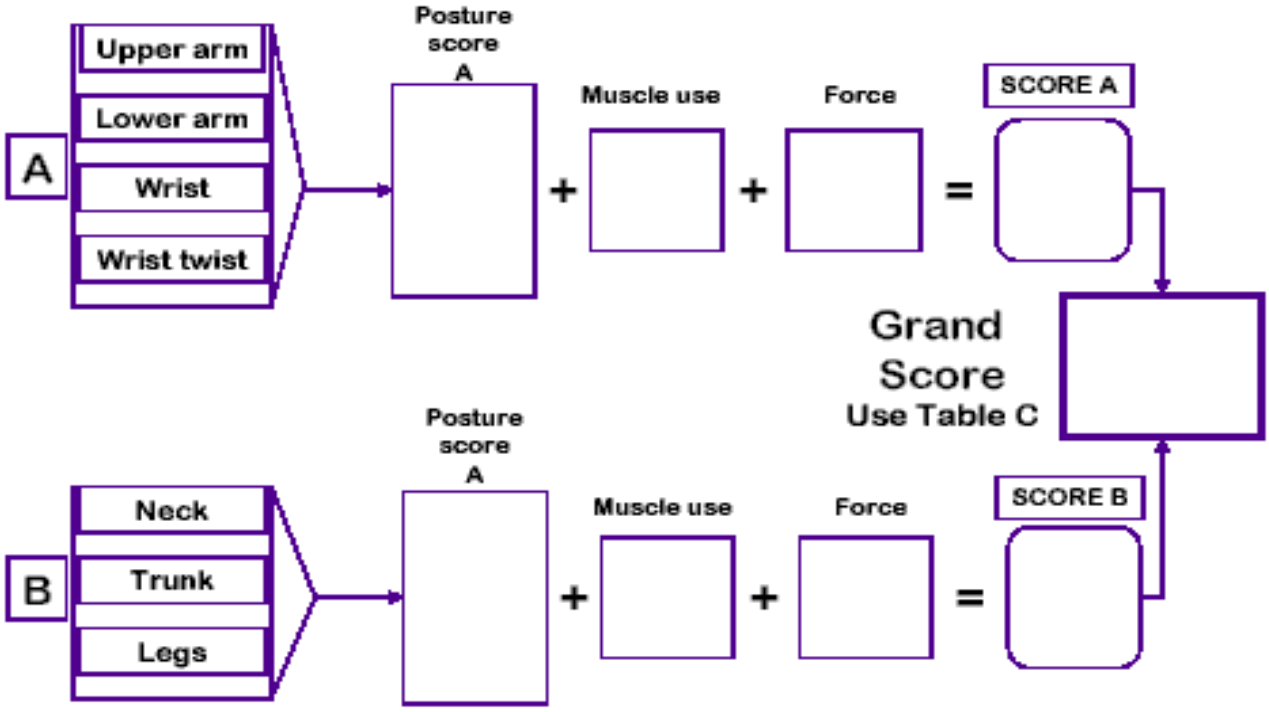

Figure 2. RULA Score Sheet

The Rapid Upper Limb Assessment (RULA) action levels gives the urgency about the need to change how a person is working. It works as a function of the degree of injury risk.

1. Action Level 1 – RULA score 1-2 means that the person is working in the best posture. There is no risk of injury from their work posture.

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2. Action Level 2 – RULA score 3-4 means that the person is working in a posture that could present some risk of injury from their work posture. This score most likely is the result of one part of the body being in a deviated and awkward position. Investigate the reasons and correct.

3. Action Level 3 – RULA score 5-6 means that the person is working in a poor posture with a risk of injury from their work posture. Investigate the reasons and change them in the near future to prevent an injury.

4. Action Level 4 – RULA score 7-8 means that the person is working in the worst posture with an immediate risk of injury from their work posture. Investigate the reasons and change them in the near future to prevent an injury.

3. OBJECTIVE OF THE RESEARCH

The objective of the current research effort is to improve ergonomic aspect of water dispenser by further focusing on how to

1. Define proper water tap height level for Indonesian people

2. Define comfort water tap valve mechanism

3.1 RESEARCH METHODOLOGY

RULA method has been mainly used to assess upper limb disorder. Several methodologies have also been applied such as Nordic Body Map assessment and anthropometric measurement approach for related human body part. As overall, the research effort has been performed by carried out these following stages as shown in this figure below.

Figure 3. Research Stages

First, research topic defined and carried out literature study. It then followed by primary data collecting for several data such as user's documentation when using water dispenser naturally, user habit investigation, anthropometric measurement and Nordic Body Map. Then it followed by RULA data processing and analysis by assessing RULA scoring sheet to investigate further improvement proposal needed.

4. RESULT AND DISCUSSION

4.1 User Habit, Nordic Body Map Result and Anthropometric Measurement

According to 50 user interview during data collecting activity, several drinking pattern as shown in the table 1.

Table 1. Activity and Water Consumption Pattern

Activity Pattern	Quantity	%	Water Consumption
1. Pattern 1 : • At Home, 15 hours • At Working Place, 9 hours	36 resp.	72	• 1200 ml • 1500 ml
2. Pattern 2 : • At Home, 14 hours • At Working Place, 10 hours	9 resp.	18	• 1000 ml • 1600 ml
3. Pattern 3 : • At Home, 13 hours • At Working Place, 11 hours	5 resp.	10	• 1000 ml • 1500 ml
Total	50 resp.	100	

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User's pattern to consume water was spread at two places and all of them consumed it at higher water volume at the office or other working place. Every user has its own preference to use drinking media such as a mug or glass with 300 ml to 500 ml capacity and 1 liter of drinking bottle. Each media has its own tapping duration and gross weight during the usage which shown in table as follows.

Table 2. Water Media Usage Data

Water Media Size	Tapping Duration	Gross Weight	User Preference	%
300 ml	15 sec	0,6 kg	11 resp.	22
500 ml	25 sec	0,65 kg	35 resp.	70
1000 ml	50 sec	1,15 kg	4 resp.	8
		Total	50 resp.	

Most of users preferred to use 500 ml water media due to proper volume, tapping time and gross weight to be handled during operate a water dispenser. At the office, the users had to refill the media at least three times a day. On the other side, this research has also documented the type of water dispenser that frequently used by the users to investigate further aspect which may affect potential upper limb disorder, as shown in the following table.

Table 3. Water Dispenser Type and Usage

Water Dispenser	Type A	Type B	Type C
Figure			
Water Tap Height	77 cm	80 cm	81 cm
Dispenser Usage	7	31	12
Percentage	14%	62%	24%

Almost 90% of users used two type of water dispenser B and C both at home and at the office, then it has been used as main focus in further observation. The height level of water tap is higher than type A which enable to enhance ergonomic posture during water dispenser operation. In fact, these following figure has shown the body posture of some water dispenser's user.

Figure 4. Body Posture on Dispenser Type B and Type C

The body posture has bended around 20° to 30° as well as the neck at various angle for around less than 1 minute depending on the media used and the expected water level. Upper arm and lower had also to open at certain degree to fit water tap height level. Anyway, all user had also to use both hands to operate water tap valve on a dispenser. Each hand has its role to grab the glass or

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other water media and to push tap button or valve. These following table has shown various water tap valve type used in this research.

Table 4. Water Tap Valve Type

Water Tap Valve	Type A	Type B	Type C
Figure			
Description	Single hand, push the water valve by water media. Other hand is free	Double hand, one to press the water valve, other to grab water media at the same height level	Double hand, one to press the water valve, other to grab water media at different height level
Dispenser Usage	10	28	12
Percentage	20%	56%	24%

According to usage description above, water tap valve type A basically may provide better comfort for user rather than other two types since there is only single hand used to operate water tap valve though there are two roles of the hand that is to grab the water media and to push the water valve simultaneously.

This research recorded the Nordic Body Map measurement as initial reference to investigate any complaint of Musculoskeletal Disorders (MSDs) for each user, which is shown in this following table.

Table 5. The Nordic Body Map Evaluation

Location		A	B	C	D
0	Pain in the upper neck	12%	66%	22%	-
1	Pain in the lower neck	48%	52%	-	-
2	Pain in the left shoulder	78%	22%	-	-
3	Pain in the right shoulder	12%	88%	-	-
4	Pain in the left upper arm	12%	88%	-	-
5	Pain in the back	12%	66%	22%	-
6	Pain in the right upper arm	12%	88%	-	-
7	Pain in the waist	12%	58%	30%	-
8	Pain in the buttock	12%	66%	22%	-
13	Pain in the right lower arm	12%	88%	-	-
15	Pain in the right wrist	12%	88%	-	-
17	Pain in the right hand	12%	88%	-	-

The table above has described that using water dispenser has raised potential MSDs on the upper limb of the body 2 especially around the neck, right shoulder, around the upper arm, in the back, waist to buttock and around lower arm as well as around right wrist and right hand. For some users who has height more than 167 cm, the pain tend to appear around upper neck, in the back, in the waist and also in the buttock.

For ergonomic improvement purposes, the respected anthropometric data has been measured as a main reference in redesigning particular part or water dispenser, especially related the water tap. The table as shown as follows.

Table 6. Anthropometric Data

Category	Average	Percentile 95
Body Height	166.12 cm	174 cm
Elbow Height	98.88 cm	103.55 cm
Lower Arm Length	30.13 cm	30.50 cm

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4.2. Rapid Upper Limb Assessment (RULA) Result

Following to RULA method, each angle of user's body posture has been measured by using two groups classification A and B. The detail assessment as shown in this following table.

Table 7. RULA Result

No	Height	Elbow Height	Lower Arm Length	Group A (Arm) / Group B (Body)	1. Upper Arm / 1. Neck	2. Lower Arm / 2. Trunk	3. Wrist Position / 3. Leg	4. Wrist Twist / -	Table Score	Activity	Load	Score	Final Score
1	157	96	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
2	160	96.5	30	A	2	1	3	2	4	0	1	5	4
				B	2	2	1	-	2	0	1	3	
3	165	97.5	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
4	164	97	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
5	164	97	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
6	165	97.5	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
7	167	98.5	30.5	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
8	167	98.5	30.5	A	2	1	2	2	3	0	1	4	5
				B	2	3	1	-	4	0	1	5	
9	165	98	30	A	2	1	3	2	4	0	1	5	6
				B	2	3	1	-	4	0	1	5	
10	167	98.5	30.5	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
11	158	96	30	A	1	1	1	2	2	0	1	3	4
				B	3	2	1	-	3	0	1	4	
12	162	97	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
13	163	97.5	30	A	2	1	3	2	4	0	1	5	4
				B	2	2	1	-	2	0	1	3	
14	166	98.5	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
15	174	103	30.5	A	2	1	3	2	4	0	1	5	6
				B	2	3	1	-	4	0	1	5	
16	167	98	30.5	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
17	165	97.5	30	A	2	1	3	2	4	0	1	5	5
				B	3	2	1	-	3	0	1	4	
18	167	98.5	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
19	164	97	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
20	169	99.5	30.5	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
21	167	98.5	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
22	165	97.5	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
23	166	98	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	

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Table 7. RULA Result (Continued)

No	Height	Elbow Height	Lower Arm Length	Group A (Arm) / Group B (Body)	3. Upper Arm / 1. Neck	4. Lower Arm / 2. Trunk	3. Wrist Position / 3. Leg	4. Wrist Twist / -	Table Score	Activity	Load	Score	Final Score
24	169	99.5	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
25	171	101	30.5	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
26	171	101	30.5	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
27	172	102	30.5	A	2	1	2	2	3	0	1	4	5
				B	2	3	1	-	4	0	1	5	
28	172	102.5	30	A	2	1	3	2	4	0	1	5	5
				B	3	2	1	-	3	0	1	4	
29	170	102	30	A	2	1	3	2	4	0	1	5	5
				B	3	2	1	-	3	0	1	4	
30	175	104	30.5	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
31	176	104.5	30.5	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
32	168	99.5	30	A	2	1	2	2	3	0	1	4	5
				B	2	3	1	-	4	0	1	5	
33	169	100.5	30	A	2	1	3	2	4	0	1	5	6
				B	2	3	1	-	4	0	1	5	
34	172	102	30	A	2	1	3	2	4	0	1	5	4
				B	2	2	1	-	2	0	1	3	
35	169	101	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
36	172	103	30.5	A	1	1	1	2	2	0	1	3	4
				B	3	2	1	-	3	0	1	4	
37	174	104	30.5	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
38	169	100	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
39	157	69.5	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	
40	155	96	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
41	170	102	30	A	2	1	2	2	3	0	1	4	5
				B	2	3	1	-	4	0	1	5	
42	150	95	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
43	161	97	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
44	165	97.5	30	A	2	1	3	2	4	0	1	5	6
				B	2	3	1	-	4	0	1	5	
45	168	98	30	A	2	1	2	2	3	0	1	4	3
				B	2	2	1	-	2	0	1	3	
46	165	97.5	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
47	166	98	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
48	167	97.5	30	A	1	1	1	2	2	0	1	3	4
				B	3	2	1	-	3	0	1	4	
49	159	96.5	30	A	1	1	1	2	2	0	1	3	3
				B	2	2	1	-	2	0	1	3	
50	167	97.5	30	A	2	1	2	2	3	0	1	4	4
				B	3	2	1	-	3	0	1	4	

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Further analysis of RULA result by user's height is shown in the following table.

Table 8. RULA Result Analysis by Height

Height	Dispenser type B		Dispenser type C	
	Quantity	Average Score	Quantity	Average Score
< 167 cm	15 resp	3.6	9 resp	3.5
≥ 167 cm	15 resp	4.1	11 resp	4.0

Average RULA score at level 3.85 (later rounded up to 4) could mean that the design of existing water dispenser especially on water tap height has not been comfortable for respected user who has height more than 167 cm. Bending body posture may cause further back pain or waist / buttock pain for certain user. So does the neck which bended more than 10° may cause preliminary injury. Furthermore, RULA score 4 can be classified into Action Level 2 which means the body posture could present some risk of injury. Therefore, the change on the water dispenser may be needed in the near future to ensure an ideal user's body posture during the operation.

4.3. Ergonomic Water Dispenser Improvement Recommendation

According to RULA method, group B has bigger influence in defining the final RULA score rather than group A. Therefore, this research has been approaching on how to minimize the score in group B as a priority then followed by minimizing the score in group A. The expected posture has been set up as ideal as possible, then expected RULA score can be settled accordingly. The expected body posture as shown in the following figure.

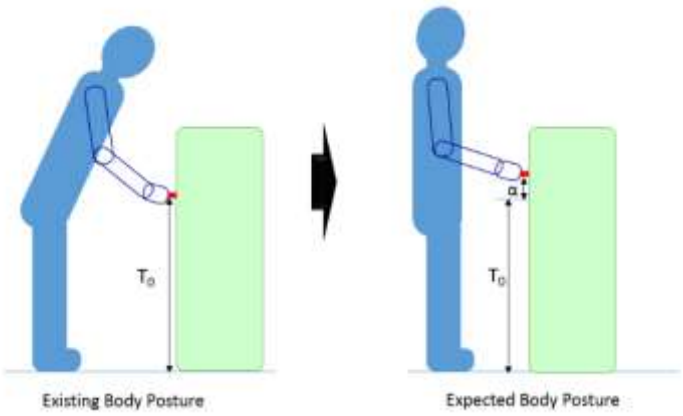

Figure 5. Expected Body Posture on Improved Water Dispenser

The expected body posture in the figure above then deployed into group B and group A below to achieve improved RULA score at least level 2 which means minimum risk and safe to implement.

Table 9. Group B : Posture Setup and Expected Score

	Neck	Trunk	Leg	Activity Score	Load Score	Expected Score B
Position	< 10^0	90^0	Normal	Static	< 2kg	
Value	1	1	1	1	0	2
Score	1					

Table 10. Group A : Posture Setup and Expected Score

	Upper Arm	Lower Arm	Wrist	Wrist Twist	Activity Score	Load Score	Expected Score A
Position	< 20^0	60^0	Neutral	Center Position	Static	< 2kg	
Value	1	1	1	1	1	0	2
Score	1						

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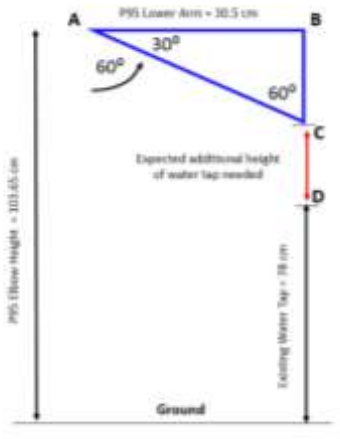
Based on expected score A 2 and expected score B 2 above, the expected final RULA score is 2. It is believed that the score could represent improved body posture when using water dispenser, there are upright back position, minimum angle in the neck area as well as improving angle around arm and hand area. Those body posture improvement required the change on water tap height level which had to be adjusted at α centimeter. By using trigonometric approach, α value measured through this following algorithm:



$$\frac{BC}{\sin 30^0} = \frac{AB}{\sin 60^0}$$

$$BC = \frac{30.5 \times 0.5}{0.86624} = 17.60 \text{ cm}$$

Then, water tap height adjustment measured as follows:

$$\alpha = \text{P95 Elbow Height} - BC - \text{Existing Water Tap Height}$$
$$\alpha = 103.55 - 17.60 - 80 = 5.95 \text{ cm} \approx 6 \text{ cm}$$

The proposed water tap height level to achieve RULA score 2 is 86 cm.

Figure 6. New Water Tap Height Level

Instead of adjusting water tap height level 6 cm higher, it is believed that modifying water tap valve has significantly contributed to achieve RULA score 2. The approach used to settle this task is on how to minimize second hand role to push or to press the existing water tap valve or button. The comparison and recommendation are shown in the table below (Scale of 5) :

Table 11. Water Tap Valve Mechanism Alternatives

Criteria	Option 1	Option 2	Option 3
Description	Push Valve (Type A)	Smart Button : Start - Stop	Voice Command Sensor
Conformance	2	4	5
Reliability	4	4	3
Serviceability	4	4	4
Cost	4	4	3
Total Value	**14**	**16**	**15**

Refer to comparison above, water tap with smart ‘start – stop’ button mechanism could deliver proper comfort for the user. One hand to grab water media and another could control water flow intermittently, at favorable cost.

5. CONCLUSION

Ergonomic water dispenser improvement has been proposed. Uncomfortable (bending) body posture when using water dispenser has been thoroughly measured and analyzed. The existing water dispenser is uncomfortable for those who has body height above 166 cm. The RULA method to assess body posture on upper limb has been completely applied. Body posture in group B has played a significant role for RULA score rather than in group A. Several simulations have been performed. Water tap height level has been proposed to adjust around 6 cm higher than the existing level. Furthermore, water tap valve type has also been proposed to adopt smart ‘start and stop’ button mechanism to enhance ergonomic level of the hand.

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