



DEVELOPMENT AND VALIDATION OF WORK MOVEMENT TASK ANALYSIS: PART 2

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ABSTRACT

This paper elucidates the second part of the development of Work Movement Task Analysis (WMTA). This part involves improvements of the WMTA previous version and validation test using experimental approach. Methods: Current study comprises of three main objectives; (1) to investigate specific muscle activity subject to the WMTA risk rating (combination of Posture and Load, (2) to determine differences of perceived exertion (Posture and Movement) subject to the WMTA risk rating, (3) to determine differences of perceived exertion (Load and Load size) subject to the WMTA risk rating. A total 14 participants with no previous history of musculoskeletal injuries handled a load (5kg and 10kg) from the low risk to the high risk workstation setting on three simulation trials. For objective (1), Electromyography (EMG) data was recorded during the tasks then demeaned, high band-pass filtered using sixth order Butterworth filter at 25-30Hz then full-wave rectification. Subsequently low-pass filtered using fourth order Butterworth filter at 4Hz and mean absolute values (MAV) were obtained. MAV were applied for normalizing the EMG data with respect to the percentage of maximal voluntary contraction (MVC) for every muscle involves. For objective (2) & (3), perceived effort determined using the Borg's scale. Results: Experiment I: Workstation height and load variations significantly affected EMG. There was a trend of increasing of muscles activity from Task 1 to Task 3 relative to the WMTA scores; Left anterior deltoid $p < 0.000$, Right anterior deltoid $p < 0.001$, Right upper trapezius $p < 0.005$, Left upper trapezius $p < 0.001$, Right erector spinae $p < 0.001$ and Left erector spinae $p < 0.000$. Experiment II—simulation 1: there was a trend of increasing of muscles activity from Task 1 to Task 3 relative to the WMTA scores. Significant different ($p < 0.007$) perceived effort of the participant for Task 1, Task 2 and Task 3. Experiment II – simulation 2: : there was a trend of increasing of muscles activity from Task 1 to Task 3 relative to the WMTA scores. Significant different ($p < 0.016$) perceived effort of the participant for Task 1, Task 2 and Task 3. Conclusions: The study provides evidence to support the validity of the WMTA tools that focused on the combination of ergonomic risk factors; Postures and Loads, Posture and Movement & Load and Load Size. This tool is expected to provide new workplace ergonomic observational tool with solid experimental validation to assess WMSDs for the next stage of the case study.

Keywords: ergonomics, musculoskeletal disorders, assessment, validation.

INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) is one of the occupational health problem encountered by workers over the world (Bernard, 1997). In Malaysia, there is increasing in trend over the years, particularly in the manufacturing sectors (PERKESO, 2013). Current technique to assess workplace WMSDs is self-report questionnaires, observations and direct measurements. Observational method is most preferred by expert and practitioners because it is easy applied directly in the field especially in epidemiological research which is involves large numbers of subjects (Dempsey *et al.* 2005; Li and Buckle, 2009). Despite the complementariness, some aspects of observational method are still critically debated particularly on the aspect of validity (Takala *et al.* 2010).

In few recent studies (Rahman *et al.* 2014; Sonne *et al.* 2012; David *et al.* 2008; McAtamney and Corlett, 1993, Hignett and McAtamney, 2000), have designed and evaluated the WMSDs assessment tool for the use in industrial environment. These approaches used in the field by ergonomics expert to assess ergonomic risks factors

that exists. Body postures encompasses neck, shoulders, arms, back and legs (Bernard, 1997; Rahman *et al.* 2014; Sonne *et al.* 2012; McAtamney and Corlett, 1993, Hignett and McAtamney, 2000). Postural were classified into several categories representing low, medium and high risk. The scientific literature suggests that WMSDs develop as a result of risk factors working combination and the overall impact is greater than the sum of the separate effects (Deverux *et al.* 2012; David *et al.* 2005; Marras *et al.* 1995; Silverstein *et al.* 1987). Other factors contributes to the WMSDs are repetitive movement, static posture, forceful exertion and vibration.

However, these previous, experimental measures is rarely used in determining the validity of the observational tools. Most of the studies applied predictive validity to address whether findings using a particular method has been associated with WMSDs. However this approach is less clear because it only emphasizes on the respondent feedback exclusively.

The initial development and validation of Work Movement Task Analysis (WMTA) was conducted in Phase I (2012-2014) and successfully achieved with inter-



rater reliability study shows substantial agreement among rater with $K = 0.70$ and significant association between WMTA score and self-reported pain or discomfort for the back, shoulder and arms and knee and legs with $p < 0.05$ (Shamsudin & Daud, 2014). That stage applied predictive validation approach and demonstrated good validation value. For phase II, current study aims to validate the WMTA tool using experimental approach that compare muscles activity involved in the three simulated tasks. Figure-2 and 3 shows WMTA tool after modification and improvement.

MATERIALS AND METHODS

Development and evaluation of WMTA Phase II involves correction and improvement of the WMTA version I and validation trial. Figure-3 shows the stages in the development process in sequential order.

After accomplished phase I of the development and validation, WMTA has been reviewed for further improvement. It involves modification some of the items to strengthen the sensitivity. For neck, flexion postures were minimized to five categories; neutral (<10 degree), slightly bending (between 10 degree and 20 degree), highly bending (>20 degree), extension (5 degree) and hyper extension (>5 degree). Neck twisting and side bending were transformed to illustration. The movement was improved from the subjective to more specific statement. For back, flexion postures were minimized to three categories that comprises three basic postures; neutral (<15 degree) trunk, slightly bending (between 20 and 45 degree) and highly bending (>45 degree). Back twisting and side bending were transformed to illustration. The movement was improved from the subjective to more specific statement. Additional risk factors were included; pulling and pushing that contributes to increase the risk of the lower back (Snook and Ciriello, 1991). For shoulder and arms, flexion postures were minimized to three referral categories that comprises three basic postures; minimum flexion, moderate flexion and above shoulder flexion. Shoulder elevation and abduction has been separated to gain more friendly understanding. The movement has been improved from subjective to specific statement. For knee and legs, four postures from the previous version is maintained, however last posture was deleted and substituted with new posture (squatting). In the term of movement, it have been improved with more comprehensible statement. Additional risk factors included; standing one leg, suspended leg and space for leg movement. Meanwhile, the load factor is maintained the existing three categories; light ($<5\text{kg}$), moderate ($\geq 10\text{kg}$) and heavy ($\geq 20\text{kg}$). In the latest version of WMTA, load size category was added. For environmental factors are maintained. However, some items were removed because of inappropriateness and there were no significant value in the assessment i.e. hand gloves, overall tempo and chair and sitting condition.

Scoring chart and process

In phase I, WMTA applied the combination of risks for specific and overall body region (Shamsudin and Daud, 2014). Therefore, in phase II (as shown in Figure-1), WMTA risk scores were maintained and improved by the combination of risk in pairs (2 dimensional matrix). Table-1 indicates the combination of risks and additional risk factors.

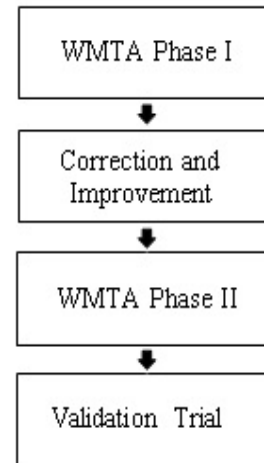


Figure-1. Development process phase II.

Procedure and experimental setting

After the correction and improvement, experimental validation phase was performed. Current study comprises of three main objectives; (1) to investigate specific muscle activity subject to the WMTA risk rating (combination of Posture and Load - experiment I), (2) to determine differences of perceived exertion (Posture and Movement) subject to the WMTA risk rating - experiment II, (3) to determine differences of perceived exertion (Load and Load size) subject to the WMTA risk rating - experiment II. These experiments concentrated on shoulder & arms and back muscles. Knee & legs and others additional risk factors were not involved in the study.

Approximately nine male participants with no previous history of musculoskeletal injuries (e.g. low back pain, shoulder pain) will be participated in the experiment I and five (3 males & 2 females) will be participated in the experiment II. Prior to start, each participant will be briefed and signed a consent form which approved by the university. Physical Activity Readiness Questionnaire (PAR-Q) (Thomas *et al.* 1992) was used as a screening method. Participants were carefully informed about the experiment procedures. Participants who answer YES to any of the following PAR-Q questions were excluded from the research.



NECK Choose & worse postural condition (P) &		Please check (✓) if involves these postures:		Movement (M)? <input type="checkbox"/> 1 >1 minute pause <input type="checkbox"/> 2 ≈ 8 second pauses <input type="checkbox"/> 3 Static/prolonged >1 minute		
 1 <input type="checkbox"/>	 2 <input type="checkbox"/>	 3 <input type="checkbox"/>	 2 <input type="checkbox"/>	 3 <input type="checkbox"/>	AND/OR" Neck Twisting <input type="checkbox"/>	 Side Bending <input type="checkbox"/>
BACK Choose & worse postural condition (P) &		Please check (✓) if involves these postures:		Movement (M)? <input type="checkbox"/> 1 below 3x per minute <input type="checkbox"/> 2 5-8x per minute <input type="checkbox"/> 3 10-12x per minute OR prolonged static Pulling OR pushing heavy load? <input type="checkbox"/> 1 Yes <input type="checkbox"/> 0 No		
 1 <input type="checkbox"/>	 2 <input type="checkbox"/>	 3 <input type="checkbox"/>	 Back Twisting <input type="checkbox"/>	 Side Bending <input type="checkbox"/>		
SHOULDER & ARMS Choose & worse postural condition (P) &		Please check (✓) if involves these postures:		Movement (M)? <input type="checkbox"/> 1 More rest (rest ≈ 1 minutes) <input type="checkbox"/> 2 Frequent (pauses ≈ 5 seconds) <input type="checkbox"/> 3 Continuously (held >1 minute) OR repeated >4 times per minute		
 1 <input type="checkbox"/>	 2 <input type="checkbox"/>	 3 <input type="checkbox"/>	 Shoulder Twisting <input type="checkbox"/>	 Side "arm" eleva. on <input type="checkbox"/>		
LOAD/TOOL CHARACTERISTICS		ENVIRONMENTAL FACTORS				
Load (L)? <input type="checkbox"/> 1 Light (<5kg) <input type="checkbox"/> 2 Moderate (≥10kg) <input type="checkbox"/> 3 Heavy (>20kg)	Load size (LS)? <input type="checkbox"/> 1 Small <input type="checkbox"/> 2 Moderate <input type="checkbox"/> 3 Big	Load stable? <input type="checkbox"/> 1 Yes <input type="checkbox"/> 0 No	Coupling (C)? <input type="checkbox"/> 1 Smooth/rounded shape <input type="checkbox"/> 2 Hard/sharp edge <input type="checkbox"/> 3 No coupling	Environmental factors? Low Light/Noise/Odor/Heat/Slippery Floor (+1 if 1 risk; +2 if >2 risks present)		
KNEE & LEGS Choose & worse postural condition (P) &		Movement (M)? <input type="checkbox"/> 1 More rest <input type="checkbox"/> 2 Some pause <input type="checkbox"/> 3 Continuously/rapidly/prolonged Standing with one leg? <input type="checkbox"/> 1 Yes <input type="checkbox"/> 0 No				
 1 <input type="checkbox"/>	 2 <input type="checkbox"/>	 3 <input type="checkbox"/>	 3 <input type="checkbox"/>	 3 <input type="checkbox"/>		
If sitting, suspended legs? <input type="checkbox"/> 1 Yes <input type="checkbox"/> 0 No		Space for legs (SL)? <input type="checkbox"/> 1 Wide <input type="checkbox"/> 2 Narrow <input type="checkbox"/> 3 Contact stress with sharp edges/hard surface				

Figure-2. Prototype works movement task analysis (WMTA) tool.



NECK

Posture (P) & Movement (M)

M \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 1

+1 if neck side bending
+1 if neck twisting

Score 2

Total score for Neck
Sum of scores 1 – 2

BACK

Posture (P) & Movement (M)

M \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 1

Posture (P) & Load (L)

L \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 2

-1 if back twisting
-1 if back side bending
-1 if involve pulling/pushing

Score 3

Total score for Back
Sum of scores 1 – 3

SHOULDER & ARM

Posture (P) & Movement (M)

M \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 1

Posture (P) & Load (L)

L \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 2

Load (L) & Load size (LS)

LS \ L	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 3

Load (L) & Coupling (C)

C \ L	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 4

+1 if shoulder elevation
+1 if side arm elevation
+1 if load not stable

Score 5

Total score for Shoulder/Neck
Sum of scores 1 – 5

KNEE & LEG

Posture (P) & Movement (M)

M \ P	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 1

Movement (M) & Space Leg of (SL)

SL \ M	1	2	3
1	1	2	3
2	2	3	4
3	3	4	5

Score 2

+1 if standing one leg

Score 3

Total score for Knee/Legs
Sum of scores 1 – 3

ENVIRONMENTAL FACTOR

Total score for Environmental factors

GRAND SCORE

Total score for Neck
+
Total score for Back
+
Total score for Shoulder/Neck
+
Total score for Knee/Legs
+
Total score for Environmental factors

	Low	Medium	High
Neck	2-3	4	5-8
Back	4-7	8-10	11-15
Shoulder/arms	8-15	16-18	19-27
Knee/legs	4-7	8-9	10-13
Environmental	0	1	2
Grand scores	18-33	34-48	49-64

	ACTION
I	ACCEPTABLE
II	TOLERABLE BUT NEED TO FURTHER INVESTIGATE AND CHANGE SOON
III	NOT ACCEPTED AND NEED TO CHANGE IMMEDIATELY

Figure-3. WMTA scoring chart and assessment process.



Experimental design

For experiment I: Participants conducted maximal voluntary contraction (MVC) for left and right Anterior Deltoid (LT DEL & RT DEL), left and right Upper Trapezius (LT UT & RT UT) and left and right Erector Spinae (LT ES & RT ES). The activity was performed in accordance to manual muscle testing procedures (Kendall *et al.* 2005; Hislop and Jacqueline, 2007). These data were used as normalization purpose for each task investigated. In this routine, percentage of MVC (%MVC) was determined. Then, participants continue to begin simulation trial (Task 1, Task 2 and Task 3) that represented low, medium and high risk conditions. Each task repeated three (3) times and then were averaged. Synchronously, EMG data was collected while performing a set of routine tasks. After accomplished all tasks, participants were required to rest approximately 10

minutes before end up the session. It aims to ensure participant's physiology was restituted to the normal condition before performing any other activities.

For experiment II: Comprised of two simulation trials; simulation 1 and simulation 2. Simulation 1 of Task 1: lifting 5kg with normal body posture and take approximately 10 seconds rest then repeat the task three times. Task 2: lifting 10kg load with slightly back flexion (15° - 20°) and arm flexion (90°) within a minute; take approximately 5 seconds rest then repeat the task five times. Task 3: lifting 10kg load with awkward back flexion and elevated arms above shoulder; take approximately 5 seconds rest then repeat the task three times. After accomplished specific simulation e.g. Task 1, participants were required to perceive how much effort that they experienced using the Borg's scale.

Table-1. Combination and additional risk factors for new revision of WMTA.

Body region	Combination of risk factors	Additional risk factors
Neck	Posture & Movement	Neck side bending Neck twisting
Back	Posture & Movement* Posture & Load*	Back side bending* Back twisting* Pulling and pushing
Shoulder & Arms	Posture & Movement* Posture & Load* Load & Load Size* Load & Coupling	Shoulder elevation Side arm elevation* Load stability
Knee & Legs	Posture & Movement Movement & Space for legs	Standing one leg
Other		Environmental factors
* The variables involved in the validation trials.		

Simulation 2 of Task 1: lifting 5kg load with small size: 45cm x 37cm x 27cm (repeated 10 times). Task 2: lifting 10kg load with moderate size: 53cm x 35cm x 30cm (repeated 10 times). Task3: lifting 10kg load with big size: 69cm x 43cm x 36cm (repeated 5 times).

Justification of the tasks selection

WMTA risk rating is based on WMTA observational tool risk indicators. In current study, it involves combination of Posture & Load, Posture & Movement and Load & Load size (Figure-4) indicatively for shoulder & arms and back regions. LOW risk scores, the rating range of 2-3, MEDIUM risk score is 4 and HIGH risk scores range of 5-6. Therefore, for Posture & Load; low risk activity (Task 1) combination of P1 and L1, medium risk activity (Task 2) combination of P2 and L2, and risky activity (Task 3) combination of P3 and L2. Posture & Movement; low risk activity (Task 1) combination of P1 and M1, medium risk activity (Task 2) combination of P2 and M2, and risky activity (Task 3) combination of P3 and M2. For Load & Load size; low risk activity (Task 1) combination of L1 and LS1, medium

risk activity (Task 2) combination of L2 and LS2, and risky activity (Task 3) combination of L2 and LS3.

Task setting

For LOW risk setting - shoulder, neck and back in the perfect postural condition (task: lifting 5kg load), for MEDIUM risk setting - Flexed shoulder and medium back bending (task: lifting 10kg load and involves moderate back flexion), for HIGH risk setting - elevated shoulder, awkward back bending and twisting (task: lifting 10kg load with extreme back flexion and twisting).

Workstations

Shelf height for low risk task was fixed perfectly with participant anthropometric measurement (stature and elbow height). Meanwhile, the shelves for medium and high risk task were adjusted to ensure the shelf was high enough for shoulder flexion and/or elevation and back flexion. In addition, for low risk task, 5kg load was used while 10kg load for medium and high risks.

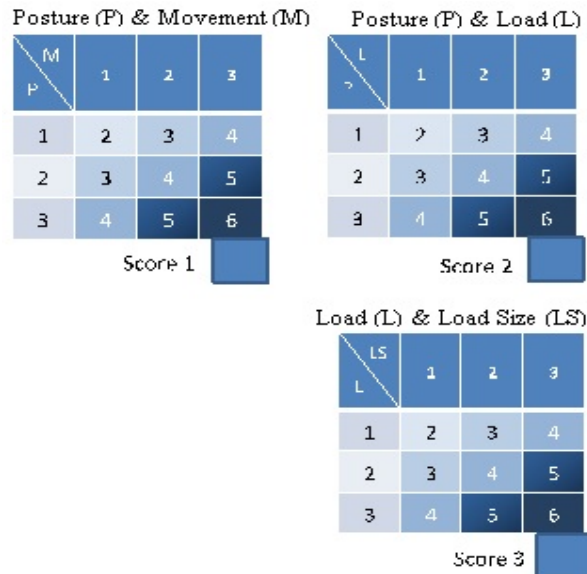


Figure-4. Scoring chart with process.

Electrodes placement and data acquisition

EMG data were collected using an eight channel EMG system (Delsys Inc., Boston, MA, USA). The sensor contacts are made of 99.9% pure silver bars measuring 10 mm in length, 1 mm in diameter, and spaced 10 mm apart.

Muscle activity was quantified using bipolar electrode that placed at LT DEL, RT DEL, LT UT, RT UT, LT ES and RT ES. Prior the experiments, the skin of targeting muscles were cleaned with alcohol to reduce skin impedance before EMG electrode attachment. EMG from the LT DEL and RT DEL was obtained by placing the electrodes at one finger width distal and anterior to the acromion. The orientation of the electrodes must in the direction of the line between the acromion and the thumb. EMG from the LT UT and RT UT was obtained by placing the electrodes at a location along the line joining the acromion and C7, at 1/2 the distance from the acromion. The orientation of the electrodes must in the direction of the line between the acromion and the spine on vertebra C7. EMG from the LT ES and RT ES was obtained by placing the electrodes at one finger width medial from the line from the posterior spina iliaca superior to the lowest point of the lower rib, at the level of L2. The orientation of the electrodes must in the direction of the line between the posterior spina iliaca superior and lowest point of the lower rib. The location electrode is determined by SENIAM recommendations (SENIAM, 2015). Meanwhile, the reference electrode was positioned on the C7 bony prominence.

Data analysis (experiment I)

The EMG data were processed using EMGworks version 4 (Delsys Inc., Boston, MA, USA) then further analyzed in Microsoft excel and SPSS version 17. All signals were demeaned, high band-pass filtered using sixth order Butterworth filter at 25-30Hz then full-wave

rectification. Subsequently low-pass filtered using fourth order Butterworth filter at 4Hz and mean absolute values (MAV) were obtained. MAV were applied for normalizing the EMG data with respect to the percentage of maximal voluntary contraction (MVC) for every muscle involves. The average MAV was determined for each electrode location during three experiment trials. MAV equation (DELSYS, 2015):

$$MAV = 1/L \sum |x_i|$$

Where,

L = Window length

X_i = Data within the window

Thereupon, the differences of the EMG were determined using Friedmann test. This method is applied to determine the differences between groups when the dependent variable being measured whether it is ordinal or continuous data.

Data analysis (experiment II)

Borg's scale which uses 1 – 10 rating. The differences of the perceived effort were determined using Friedmann test.

RESULTS

Experiment I: From total of 15 male participants included in the experiment I, nine participants were selected to participate in the current experiments. Six participants excluded because did not meet the PAR-Q requirement. Table-2 shows the characteristic of the participants. On average participant aged around 19-23 years old. The participants comprise of the Occupational safety and health (OSH) and Environmental Health (EH) students.

EMG data are presented in Table-3. Three simulation trials for each Task (Task 1, Task 2, and Task 3) were averaged. Overall, there was a trend of increasing of muscles activity from Task 1 to Task 3. Based on the Friedmann analysis, there was significant different ($p < 0.000$) for muscles activity of the LT DEL for Task 1, Task 2 and Task 3. Task 3 ($r = 3.00$) indicates the highest muscle activity followed by Task 2 ($r = 1.89$) and Task 1 ($r = 1.11$). There was significant different ($p < 0.001$) for muscles activity of the RT DEL for Task 1, Task 2 and Task 3. Task 3 ($r = 3.00$) indicates the highest muscle activity followed by Task 2 (1.78) and Task 1 (1.22). There was significant different ($p < 0.001$) for muscles activity of the LT UT for Task 1, Task 2 and Task 3. Task 3 ($r = 2.78$) indicates the highest muscle activity followed by Task 2 (2.22) and Task 1 (1.00). There was significant different ($p > 0.005$) for muscles activity of the RT UT for Task 1, Task 2 and Task 3. However, Task 3 and Task 2 share the similar rank ($r = 2.44$) while Task 1 ($r = 1.11$). There was significant different ($p < 0.000$) for muscles activity of the LT ES for Task 1, Task 2 and Task 3. Task 3 ($r = 2.89$) indicates the highest muscle activity followed



by Task 2 ($r = 2.11$) and Task 1 ($r = 1.00$). There was significant different ($p < 0.001$) for muscles activity of the RT ES for Task 1, Task 2 and Task 3. Task 3 ($r = 2.56$) indicates the highest muscle activity followed by Task 2 ($r = 2.44$) and Task 1 ($r = 1.00$).

Table-2. Characteristics of participants. Mean and standard deviation are given for experiment I.

Variables	Mean	SD
Age (years)	21.22	2.28
Height (cm)	172.11	7.34
Weight (kg)	61.72	13.34

Experiment II – simulation 1: Of total six male participants included in the experiment I, five participants were selected to participate in the current experiments. One participants excluded because not meet the PAR-Q requirement. Table-4 shows the characteristic of the participants. On average participant aged around 19-23 years old. The participants comprise of the Occupational safety and health (OSH).

Perceived effort data are presented in Table-5. Three simulation trials for each Task (Task 1, Task 2, and Task 3) were averaged. Overall, there was a trend of increasing of perceived effort from Task 1 to Task 3. Based on Friedmann analysis, there was significant different ($p < 0.007$) perceived effort of the participant for Task 1, Task 2 and Task 3. Task 3 ($r = 3.00$) indicates the highest perceived effort followed by Task 2 ($r = 2.00$) and Task 1 ($r = 1.00$).

Experiment II – simulation 2: The same number of participants like experiment II – simulation 1 (refer Table-4). Perceived effort data are presented in Table-6. Three simulation trials for each Task (Task 1, Task 2, and Task 3) were averaged. Overall, there was a trend of increasing of perceived effort from Task 1 to Task 3. Based on Friedmann analysis, there was significant different ($p < 0.016$) perceived effort of the participants for Task 1, Task 2 and Task 3. Task 3 ($r = 2.70$) indicates the highest perceived effort followed by Task 2 ($r = 2.30$) and Task 1 ($r = 1.00$).

DISCUSSION

This study was conducted to validate the WMTA tool using simulation trials. According to the experiment I results, there were increasing trends of the muscle activity for the three set of tasks. Task setting created by the lowest to highest risk (Task 1 < Task 2 < Task 3). According to Kumar (1996) it is possible to establish a relationship between external loads held in hand and muscle load. Handling the heavy loads involves high levels of muscle activity on the shoulder and lower back (Bernard, 1997; Marras *et al.* 2010). According to the current results, the greater effort required for lifting the box that explain the differences of each task. Lift the 5kg

load with the neutral posture is lower than lift the 10kg with moderate and risky postures.

In addition, the workstations height clearly play a role contributed towards the increasing the muscle activity. Higher muscular activity on Deltoid and Upper trapezius muscles was recorded when subject transfers the load above the shoulder height. It contributed 24.4%, 28.3%, 14.8% & 5.40% increasing from Task2 to Task3 for LT DEL, RT DEL, LT UT and RT UT. This result is consistent with other literatures (Habes *et al.* 1985; Nielsen *et al.* 1988; Anderson *et al.* 2007). Meanwhile, when the arm is move away from the body (either sagittal or frontal plane), greater arm angles and internal load generated. The association between awkward posture and shoulder disorders is well documented in the literatures (Bernard, 1997, Larsson *et al.* 2007).

According to the experiment II – simulation 1 results there were increasing trends of perceived effort for the three set of tasks. This situation occurs because of repetitive movements affects the physiological system of muscles and tissues. During muscle contractions the tendon is exposed to mechanical load both along the tendon and from surrounding tissues. This tension leads to mechanical visco-elastic deformation. This requires adequate time period for recovery, however during the period of increased tension and insufficient recovery blood supply and metabolism of the tendon is affected (Kilbom, 2000). This situation considers the movement without sufficient rest gains high probability to cause tendons injury. Combination of repetitive movement with awkward postures is well documented in the literatures (Waters *et al.* 1993; Bjelle *et al.* 1981; Herberts *et al.* 1984).

According to the experiment II – simulation 2 results there were increasing trends of perceived effort for the three set of tasks. Extensive study describes load factor individually or in combination of work postures and load (Bernard, 1997). However, there is insufficient evidence of the combination of load and load size which affects the musculoskeletal disorders. This study focus to the load size involves shoulder abduction and flexion. Big size of the load requires subject abducted the shoulder. As the arm is abducted and flexed, the angle between the torso and upper arms also increases. This situation lead the space between the humeral head and acromion becomes narrows and lead to exert more in order to stabilize the big compared to the small size which have equal weight.

Indeed, the scope of current study was to validate the WMTA tool so the intention to conduct detail analysis was not included e.g. fatigue. Hence, the experimental findings is sufficient to prove that WMTA tool is valid and appropriate to evaluate musculoskeletal risk factors on the field focus on the upper limbs region. However the limit of current study was current study exclusively focus on the three main muscles; neck, shoulder and back. Current study also limited for two combinations of risk factors which is Posture & Load, Posture & Movement and Load & Load Size. For future recommendation, the study design must include other risk factors e.g. posture of the legs, movement of legs, coupling, etc.



In the experiment II, limitations of the current study mainly focus on the participant's perceived effort that not specifically indicates the fatigue of the specific muscles (back and shoulder). However, in the current study, perceived effort was relevantly adequate because the tasks were set to stimulate effort for shoulder and back

muscles. Higher Borg's scale indicates the higher effort which is required for the specific task. In the future work, the researcher should apply experiment that investigates specific muscles fatigue of movement.

Table-3. Average value of simulation trials of LT DEL, RT DEL, LT UT, RT UT, LT ES, RT ES for Task 1, Task 2 & Task 3.

N	LT DEL			RT DEL			LT UT		
	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3
S1	8.23	16.86	22.10	18.02	26.56	31.84	10.41	28.40	30.44
S2	12.35	28.11	35.11	20.38	24.91	39.74	13.58	51.89	51.86
S3	5.41	13.07	17.59	11.75	15.27	21.60	21.86	65.05	84.16
S4	9.92	10.47	15.89	10.59	9.85	16.36	14.37	33.70	38.46
S5	21.28	17.97	28.20	23.81	20.71	27.64	10.11	42.36	58.38
S6	3.40	9.24	12.91	6.19	11.27	14.45	13.91	31.95	42.08
S7	10.18	15.09	27.68	13.13	17.49	24.63	8.12	20.47	17.03
S8	10.17	18.05	26.85	18.47	22.42	26.61	27.48	90.29	99.62
S9	15.33	33.45	40.31	10.15	12.70	28.90	5.75	29.40	39.89

N	RT UT			LT ES			RT ES		
	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3
S1	13.90	26.77	37.95	28.27	46.22	54.19	9.13	38.96	39.09
S2	23.78	45.93	42.74	10.22	24.56	37.28	4.34	37.39	35.02
S3	22.01	48.60	54.59	17.52	26.38	60.34	6.13	25.72	28.47
S4	28.03	43.10	56.41	8.99	17.51	25.77	5.21	20.02	19.62
S5	10.89	16.46	21.82	16.79	17.66	38.05	6.07	17.74	18.45
S6	9.99	24.94	31.03	3.30	8.96	18.64	2.49	9.78	12.31
S7	15.75	23.82	14.72	21.63	40.14	39.57	17.18	30.08	28.40
S8	112.79	244.07	243.77	12.90	25.61	43.84	10.85	22.57	22.63
S9	11.25	35.70	35.47	13.07	31.17	40.95	12.08	56.67	32.60

Table-4. Characteristics of participants. Mean and standard deviation are given for experiment II (simulation 1 & 2).

Variables	Mean	SD
Age (years)	23.00	0.71
Height (cm)	161.00	7.21
Weight (kg)	67.60	19.15

Table-5. Average value of experiment II - simulation 1 for Task 1, Task 2 and Task 3.

n	Task 1	Task 2	Task 3
S1	3.33	5.67	7.33
S2	2.67	5.00	5.67
S3	2.67	5.00	6.33
S4	3.00	4.33	5.00
S5	3.67	4.67	5.67
MEAN	3.07	4.93	6.00

Table-6. Average value of experiment II - simulation 2 for Task 1, Task 2 and Task 3.

n	Task 1	Task 2	Task 3
S1	4.33	6.00	6.67
S2	4.33	5.00	4.67
S3	3.33	4.67	5.00
S4	3.33	5.00	5.00
S5	4.00	5.67	6.00
MEAN	3.87	5.27	5.47

CONCLUSIONS

In this study, designed WMTA observational tool in comparison to other observational tools has the following advantages: A main advantage it applies experimental study to validate the method. WMTA feasible for dynamic work tasks instead of static. In term of sensitivity, WMTA promotes combination of risks potentially which causes WMSDs. WMTA also clear, precise and simple that help untrained individual to cultivate good safety culture and behavior. This tool is expected to provide new workplace ergonomic



observational tool to assess WMSDs in the case study which involves wide range of industries setting in Malaysia.

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