The Critical Variables for the Risk Assessment Associated with Pushing and Pulling of Wheeled Equipment in the Workplace: Subject Matter Expert Review

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Abstract

The current study aimed to determine the critical variables for the observational-based assessment of wheeled equipment's pushing and pulling (PP) based on the inputs from subject matter experts (SMEs). Therefore, the feedback from SMEs in Malaysia and globally were gained through a self-administered online questionnaire. The critical variables for PP assessment were chosen based on the content validity ratio above 0.59, given that the number of expert panels was 11. Thirteen variables or 56.5% (type of device, wheel diameter, handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor condition, obstacles along route, congestion and gender) from the 23 variables evaluated, were found to be essential variables in assessment of PP activities. It was observed that many of the variables were not considered in the present observational-based assessment tool for PP activities. Therefore, it is reasonable to develop a new assessment tool for PP activities by considering the input from the SME.

Keywords
Pushing and pulling, subject matter experts, ergonomics, observational-based risk assessment, wheeled equipment

1. Introduction
Musculoskeletal injuries have been frequently reported in labour-intensive industries due to a wide range of manual handling activities (Lind et al. 2019, Abdullah and Dawal 2020, Yang et al. 2020, Ariyanto et al. 2021, Chinichian et al. 2021). Thus, risk mitigation is adopted by introducing PP using wheeled equipment (Resnick and Chaffin 1995, Haslam et al. 2002, Granata and Bennett 2005, Jung et al. 2005). Nevertheless, PP is not as simple as its acceptance due to biomechanics' complexity during the PP activities (Marras et al. 2009). PP activities are known to result in other forms of injuries (Botti et al. 2020, Haslam et al. 2002). The Health Council of the Netherlands (2012), Hoozemans et al. (2014) and Yang et al. (2020) reported that lower back and shoulder injuries are prevalent due to the PP activities. Additionally, Yang et al. (2020) asserted that accident cases were the highest during PP tasks compared to other manual handling tasks.

Risk management in reducing musculoskeletal injury cases to the workplace begins with risk assessment (NIOSH 1997, Zare et al. 2020). Risk assessment is undertaken by the portfolio of occupational safety and health (OSH) practitioners (National Council of Occupational Safety and Health, 1994). David (2005) recommended that ergonomics risk assessment can be divided into three approaches. The approaches suggested are self-report, observations methods (simple and advanced technique) and direct measurement. Observation methods often fulfil the requirements of OSH practitioners due to speed and cost-effectiveness (David 2005). There are numbers of methods related to the assessment of PP. Among the observational-based assessments is the Key Indicator Method-Pushing/Pulling (KIM-PP) (Steinberg 2012), Risk Assessment of Pushing and Pulling (RAPP) tool (Okunribido 2013) and the Push and Pull Check (DUTCH) (Douwes et al. 2018). Nevertheless, KIM-PP (Steinberg 2012), RAPP (Okunribido 2013) and DUTCH (Douwes et al. 2018) have some limitation.

The RAPP and KIM-PP assessments did not include handle height, although it is a critical contributor to the development of musculoskeletal disorders (MSD) during PP tasks. (Chaffin et al. 1983, Al-Eisawi et al. 1999, Hoozemans et al. 2004, Marras et al. 2009, Kumar et al. 2021). Similarly, task duration was excluded from the RAPP and DUTCH assessments, although the importance for its inclusion was proposed by Van Der Beek et al. (1999). Task duration is essential in understanding the total exposure rate in the development of MSD, increasing the risk for manual handling injuries (Limerick 2012). Another limitation of the RAPP and DUTCH assessments is that there is no evidence of reliability study conducted to prove their effectiveness, although it is incredibly significant as an assessment tool to prove reliability (Rohani et al. 2018, Zetterberg et al. 2019). A reliability test has been conducted for KIM-PP by Douwes et al. (Douwes et al. 2018). The validity of the tools is essential (Sukadarin et al. 2015). However, no evidence is available on the validity of the tools. Thus, developing a new observational assessment tool for PP activities is required while evaluating all the critical variables for PP risk factors. During the development stage, a reliability and validity study must be conducted to prove the effectiveness of the assessment tools.

There are a few techniques in developing the assessment tool, such as consulting the SMEs and referring to the literature review (Ferreira and Smith 2007, Steinberg 2012, Okunribido and Lekka 2014, Health and Safety Executive 2016, Lind et al. 2019). The feedback by the SME will be explored in this research by identifying the critical variables for the development of the PP assessment tool. SME consultation is often inclined towards the qualitative approach. Nevertheless, the current research used the quantitative method by calculating the content validity ratio for decision-making. This approach has not been utilised in assessment method development thus far.

2. Methods

A widely used content validity method developed by Lawshe (1975) was used to identify the critical variables for the PP assessment tool. Lawshe (1975) introduced the content validity ratio to measure the agreement among the SME. This method has been widely employed during questionnaire development and validation (Ghazali et al. 2018, Taib and Fauzaman 2019). Hence, the method is also used to develop the assessment tool in the current study. The framework developed by Jung et al. (2005) and Mack et al. (1995) was adapted with the incorporation of additional variables such as temperature (Snook and Ciriello 1974), handgrips (Ayoub and Dempsey 1999), task duration (Ayoub and Dempsey 1999) and positioning accuracy (Marras et al. 2009) as shown in Figure 1 is proposed by the current study. Obstacles, slopes, stairs and curbs were combined as the obstacles en route in the present study. Thus, the total variables employed in this study were 23 variables.

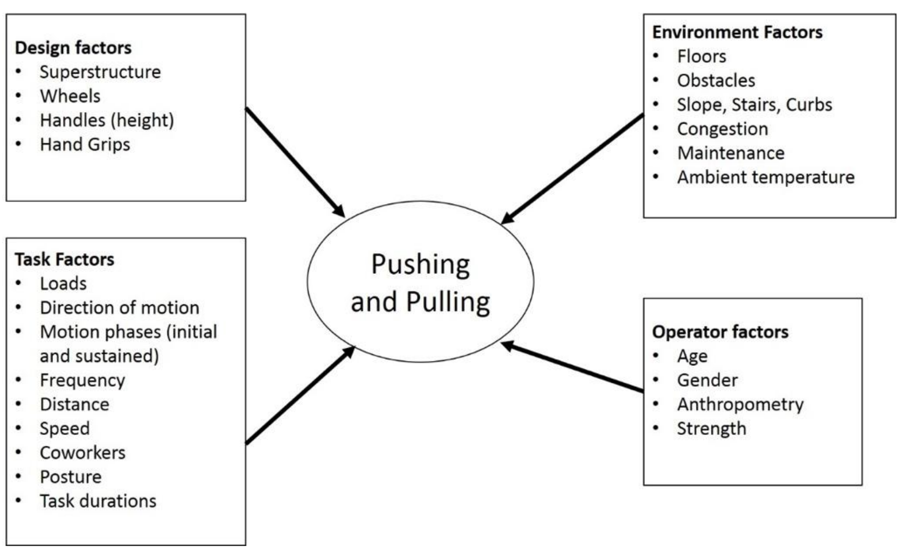

Figure 1. Pushing and pulling framework

The validation process was undertaken, as shown in Figure 2.

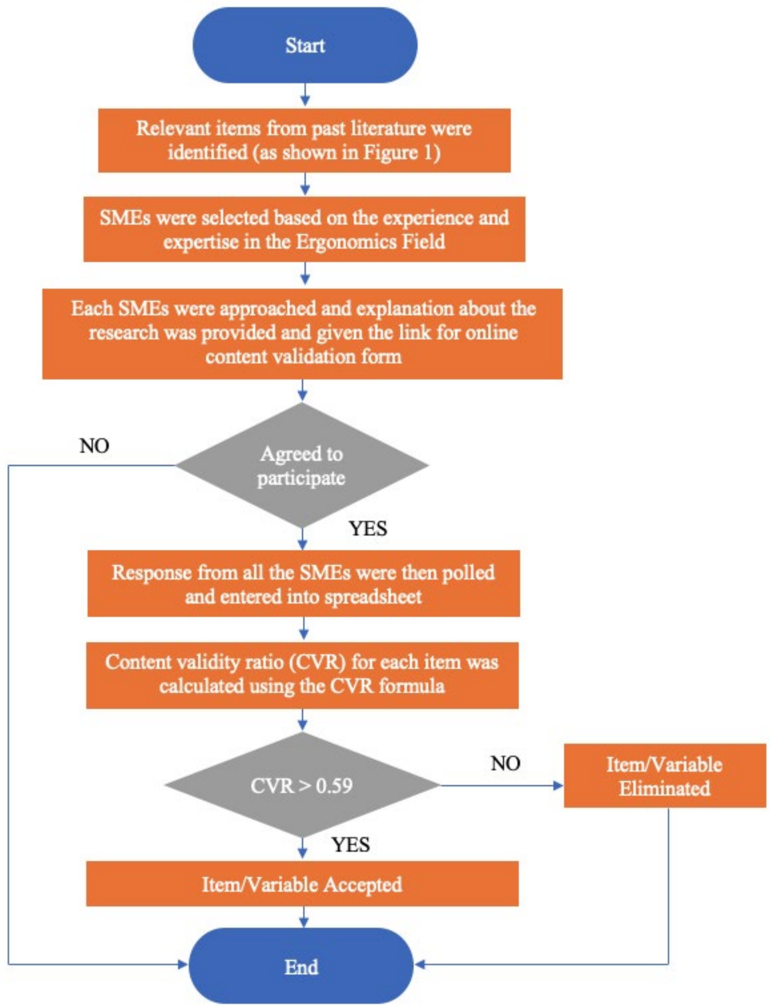

Figure 2. Validation process

The online survey questionnaire was developed based on the PP framework, as shown in Figure 1. The SMEs were shortlisted based on the inclusion criteria set for the present study. The inclusion criteria for the SMEs consist of the following:

- An expert with experience of more than five years in the field of ergonomics;
- An expert from Malaysia and globally;
- Made up of two categories: Professional expert and field expert (Rubio et al. 2003); and
- Professional experts consist of academicians and researchers, whereas field experts are those doing consultation work.

Each individual SME was contacted on a personal basis. The researchers explained the research objective and the SMEs' roles in the research. The SMEs were provided with online forms to self-administer their inputs. The SMEs were questioned based on their experience and knowledge to provide feedback on whether the 23 items listed should be incorporated into the assessment tool for PP. The SMEs were provided with the following options:

i. Not necessary
ii. Useful but not necessary
iii. Essential

The feedback from all the SMEs was entered into a spreadsheet. The Content Validity Ratio (CVR) values for each item were calculated based on the formula shown in Figure 3 below:

Content validation ratio (CVR),
CVR = (ηe – N/2) / (N/2)
ηe = number of panellist indicating essential,
N = total number of panellist

Figure 3. CVR formula

The value of CVR ranged from zero to one (Lawshe 1975, Lewis et al. 2005). The estimated CVR value equal to or above the standard value demonstrated that the item was accepted. The value that does not fulfil the criteria will be eliminated. The number of SMEs in this study is 11. The items with CVR less than 0.59 was deleted, whereas more than 0.59 was accepted.

3. Results and Discussion

The demographics profile of the SMEs (n=11) consists of three experts from international and eight from Malaysia. Five SMEs are professional expert and field experts. One professional expert is an academician, and five are field experts. Table 1 below shows the demographics characteristics of the expert panel. The median years of experience for SMEs is 16 years. Among the SMEs, one is a bachelor's degree graduate, three master's degree graduates, and six are doctorate holders.

Table 1. Demographics characteristics of SMEs

Expert	Academic Qualification	Years of experience	Designation of SME	Nationality
1	PhD	36	Academia / researcher and Ergonomics Consultant	United Kingdom
2	MSc	21	Ergonomics Consultant	Malaysia
3	MSc	8	Ergonomics Consultant	Malaysia
4	PhD	30	Ergonomics Consultant	Malaysia
5	MSc	19	Academia / researcher and Ergonomics Consultant	Malaysia
6	B.Eng	5	Ergonomics Consultant	Malaysia
7	PhD	13	Academia / researcher and Ergonomics Consultant	Malaysia
8	PhD	11	Academia / researcher and Ergonomics Consultant	Malaysia
9	MSc	18	Ergonomics Consultant	Malaysia
10	PhD	13	Academia / researcher	Indonesia
11	PhD	16	Academia / researcher and Ergonomics Consultant	India

Figure 4 exhibits the results of CVR based on Lawshe's calculation and CVR interpretation. The accepted variables were included in the risk assessment of PP of wheeled equipment.

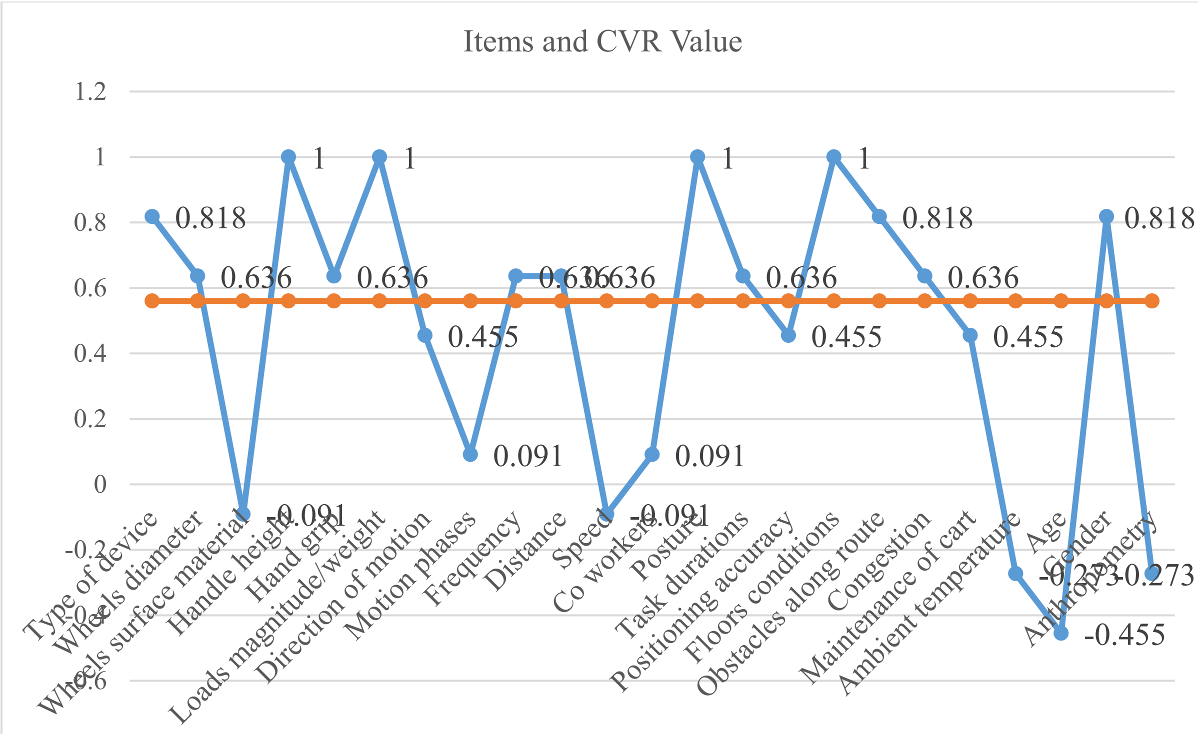

Figure 4. Items and CVR value

Thirteen variables (type of device, wheel diameter, handle height, handgrip, load magnitude, frequency, distance, posture, task duration, floor condition, obstacles along route, congestion and gender) out of the 23 variables were observed as critical variables for inclusion in the assessment of PP. The present study employed the quantitative approach for the selection of variables to be included during the items selection process during the development of risk assessment tools, unlike the previous assessment tools that were developed based on the qualitative approach of SME feedback (Ferreira and Smith 2007, Steinberg 2012, Okunribido and Lekka 2014, Health and Safety Executive 2016, Lind et al. 2019). Table 2 shows the tabular comparison between the variables included in the present observational method for PP and SME.

Table 2. Comparison between PP assessment tools and SME review

Variable Category and Variable	Assessment Tools			**SMEs**
	KIM-PP[14]	**RAPP** [10]	**DUTCH** [15]	
Type of device	•	•		•
Wheel's diameter				•
Wheels surface material				
Handles height			•	•
Handgrip		•		•
Loads magnitude	•	•	•	•
Direction of motion (pushing /pulling)				
Motion Phases (initial and sustained)				
Frequency	•	•	•	•
Distance	•	•	•	•
Speed	•			
Co-workers				
Posture	•	•		•
Task Duration	•			•
Floor conditions	•	•		•
Obstacles along route	•	•		•
Congestion				•
Maintenance	•	•		
Ambient temperature		•		
Age				
Gender	•		•	•
Anthropometry				
Strength				
Others	•a,b	•c		
Coverage of variables	11/23	11/23	5/23	13/23

Note:
a - Positioning accuracy
b - Slope, stairs, and curbs
c - Unstable load; the load is large and obstructs view; the load is sharp, hot and could damage touch; poor lighting conditions; strong air movements; personal protective equipment obstruct the work.

Eleven variables were included in the KIM-PP and RAPP assessment tools, while five variables were included in the DUTCH tool. The current SME review resulted in 13 variables with three variables (load magnitude, frequency and distance) similar to the other tools. The significant effects of the load magnitude during PP activities has been reported previously concerning heart rate (Datta et al. 1983, Van Der Beek et al. 2000), PP force (Resnick and Chaffin 1996, Al-Eisawi et al. 1999, Van Der Beek et al. 2000, Ciriello et al. 2001, Jansen et al. 2002, Laursen and Schibye 2002, Hoozemans et al. 2004, Bennett et al. 2008), oxygen intake (Van Der Beek et al. 2000), movement time (Woldstad and Chaffin 1994), lateral shear (Hoozemans et al. 2004, Marras et al. 2009), anterior and posterior shear force (Lett and McGill 2006, Marras et al. 2009), low back movement (Hoozemans et al. 2004, Lett and McGill 2006) and spine compression (Hoozemans et al. 2004, Lett and McGill 2006, Marras et al. 2009).

Van Der Beek et al. (1999) justified that the frequency of repetition will lead to the cumulative effect on employees in the development of musculoskeletal injuries. The element was further recommended by Hoozemans et al. (1998) to be included during the assessment of PP. The maximum acceptable force reduces proportionally with the increase of PP distance (Snook et al. 1970, Snook 1978, Snook and Ciriello 1991, Mital et al. 1997, Steinberg 2012). Four variables corresponding with the KIM-PP, RAPP assessment and the SME review are the type of device, posture, floor conditions and obstacles along the route. The research has demonstrated that the variables are critical for consideration during observational-based assessment for PP activities' tools. It is recommended that inputs from OSH practitioners (Krishnan and Rahman, 2020) and evidence from the epidemiology studies include finalising the criterion for the assessment tool.

4. Conclusion

The feedback provided by the SMEs was essential in determining the variables required to assess PP activities in industries. Their feedback is critical considering the work they undertake in the research and their roles in improving workplace ergonomics. Overall, 54.2% (13/23) of the variables were considered essential when performing the risk assessment of PP tasks based on the feedback received from the SME. Therefore, a new assessment tool for PP activities should be developed by considering the feedback from the SMEs. The new assessment tool should incorporate reliability, validity, and usability factors as previously developed for pen and paper-based risk assessment tools (Rahman et al. 2011, Rahman et al. 2012, Razak and Rahman 2017). This study has established a methodology of utilising Lawshe's CVR method to select variables through a quantitative process to develop a risk assessment tool.

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