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RAPh's Scale: a Scale for Measuring Individual's Effort and Exertion during Physical Work

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ABSTRACT

This paper presented a scale for measuring individual's effort, exertion and fatigue during physical work and suitable for industrial applications. This scale is a subjective physical measurement tool. It can be performed through self-administered or through interviews (by an assessor or a researcher). Similar to other work intensity and physical exertion subjective rating tools, the main purpose of the RAPh's Scale is to serve as an assessment tool to measure activity intensity level which can contribute to the development of musculoskeletal disorders. Structure and instruction on usage of RAPh's Scale are presented. Example of case study using RAPh's Scale among maintenance workers at bus service company are included in this study.

Keywords: Rating of Perceived Exertion, Physical Intensity

1. INTRODUCTION

The subjective rating scale such as Rating of Perceived Exertion (RPE) scale [1] is a valuable tool for assessing the intensity of physical effort during heavy and physically demanding work. In works that involve high force activities such as heavy lifting, carrying and etc, monitoring workload is essential to prevent excessive fatigue and high forces eventually reduce the risk of injuries. The scale allows workers and assessor/researcher to evaluate how physically demanding a task feels by considering factors such as muscular strain, breathing difficulty, and overall effort. By translating subjective perceptions into measurable ratings, the scale supports effective workload management, helps identify tasks that may exceed safe exertion levels, and contributes to improved occupational safety and productivity in heavy and physically demanding work environments. The widely use scale such as Borg Scale [1] shows that this tool is very beneficial in assessing intensity of physical work and measure the risk for musculoskeletal injuries. Besides assessing physical work, subjective rating scale also in different areas of applications [1][2][3][4][5].

2. THE RAPh's SCALE

In this study, the main objective was to develop a new subjective rating scale tool for industrial application known as RAPh's Scale. Similar to other subjective rating scale, it can be used to assess physical intensity during work. It subjectively measures how hard the body work during a physically demanding activity based on how the respondent feels during the task being performed.

Compare to other available subjective rating scale, the main advantage of RAPh's Scale is it allows the respondent to used combinations of factors namely effort, difficulty, load and force (as shown in **Table 1**) to translate their subjective feeling of intensity level to more measurable rating scale.

The assessment using this scale can be performed through self-administered (by respondent) or through interviews (by an assessor or a researcher).

3. INSTRUCTION ON HOW TO USE THE RAPh's SCALE

RAPh's Scale is a simple numerical list and the number gives an indication of the intensity of a physical activity being performed (sample RAPh's Scale score sheet attached in the appendix). The RAPh's Scale has 10 numerical scores (1-10). The scores are relative scores and not absolute scores. '1' score indicates that the is no or extremely least respondent's capacity and '10' indicates the most or approaching maximum respondent's capacity. This tool also provides respondents with effort, difficulty, load and force guidance (as shown in **Table 1**) to decide the score for a particular physical task being assessed.

These are some important instructions when performing the assessment.

1. Respondent can choose to assess **a particular event during the task**, **a few events during the task** or the **overall task**. It is recommended to assess the worst-case scenario.
2. The assessment can be conducted based on **effort, difficulty, load** or **force** factors **individually** or any **combinations** of these factors.
3. If only one factor considers during assessment, take the chosen score as the score for that particular assessment activity. On the other hand, if combinations of factors to be used, choose the highest score as the score for that particular assessment activity
4. Participants or respondents are requested to rate their effort and exertion on the scale during the activity.

Table 2 shows some examples of the indicators that can be used to assist in determining the score. This just the indicators and may not be applicable for certain situation. **Respondents' response** and **opinion** should be the **main indicator** as they are the one that feel the intensity of the activity being performed.

Table 1: RAPh's Scale scores

Score	Effort	Difficulty	Load or Force	Action Level	Risk Level
1 Extremely or very low	Extremely or very light, nothing at all, negligible	Extremely or very easy	Extremely or very low/light, nothing at all, negligible	Acceptable – Negligible risk	No Risk
2 Low	Light	Easy	Low / light	Further Investigation, Change may be needed	Low Risk
3 Low to Medium	Moderate somewhat strong, hard, tough or difficult	Moderate or somewhat difficult	Moderate or somewhat heavy, high or strong	Further Investigation (Investigate closely), Change soon	Medium Risk
4 Medium					
5 Medium to High	Strong, hard, tough or difficult	Difficult	Heavy, high or strong	Further Investigation (investigate urgently), implement change	High Risk
6 High					
7 High to Very high	Very strong, hard, tough or difficult	Very difficult	Very heavy, high or strong	Implement Change immediately	Very High risk
8 Very high					
9 Very High to Extremely high	Extremely strong, hard, tough or difficult	Extremely difficult	Extremely heavy, high or strong		
10 Extremely high					

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Table 2: Indicators of the intensity

Score	Indicator
1	• No indication of any particular effort • No muscular effort • Very easy
2	• Minimal effort • Minimal muscular effort • Easy
3-4	• Force needs to be exerted • Require some effort • Somewhat difficult • Manageable and sustainable • sustained for long periods
5-6	• Force obviously high / muscle seem to have significant efforts • Difficult but still able to continue • Worker able to perform the task with significant efforts • Need assistant – individual seem comfortable but still apply significant effort • Posture incline (not extremely incline) towards direction of force or to support force • May require one shock force to successfully complete the intended task • Seems struggling to perform the task • Obvious/significant effort but unchanged/slightly change facial expression • challenging but manageable
7-10	• Worker needs to push themselves with extreme effort – push hard • Try a few times before successfully completed the forceful intended task – for example to open something etc • Require assistant to complete the task • Very/extremely difficult • Extreme/ severe Posture toward or to support force • Very fatiguing – sometimes takes breaks and continue again to complete the tasks • Restricted/ constrained/ confined space with high force • Need support to apply extra force • Require shock force mor than once to complete the intended task • Use shoulder/trunk force • Seems very struggling to perform the task • Sometimes body start to shaking • Changed facial expression - very stressful/ very difficult/ maximum effort • Unsustainable for long periods • Sustainable for a very short time • Close to or at the individual's limit • Force near maximum level that the worker can apply

4. THE CASE STUDY

Study was conducted at engineering department one of the bus service providers in Malaysia. In engineering department, most tasks are physically demanding especially in maintenance activities. It involves tasks such as replacing heavy parts at small, narrow and restricted space and etc.

A few tasks were chosen to demonstrate the use of RAPh's Scale. Those chosen tasks were as follow:

1. Air bellow replacement
2. Brake disc, brake pad and calliper replacement
3. Oil sump tank replacement

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4.1 Air bellow replacement

Air bellows are critical components of a bus air suspension system, designed to support vehicle weight, absorb road shocks, and maintain ride comfort and stability. Over time, air bellows are subjected to continuous pressure cycles, load variations, environmental exposure, and road debris, which can lead to wear, air leaks, cracking, or complete failure. A damaged or deteriorated air bellow can negatively affect ride quality, vehicle handling, passenger comfort, and overall safety, as well as place additional stress on other suspension components.

Therefore, air bellow replacement is an essential maintenance activity to ensure the bus suspension system operates efficiently and reliably. In air bellow replacement activity, worker needs to remove air bellow in narrow space and really tight space. Worker needs to unfasten the bold and nuts the secure the air bellow to the bus frame. It involves high forces in tights space with limited movement of the tool. Worker complains to have difficulty and hard mainly due to physical demanding task in tight and narrow space. During activity, the worker shows facial expression showing hard and difficult task being performed. **Figure 1** shows the RAPh's Scale score as responded by the worker. The score given is 6 (High Risk).

RAPh's Scale Scoresheet

Task Description	Score		Effort		Difficulty		Load or Force	Action Level	Risk Level	RAPh's Scale Score
Rear bellow replacement 	1 Extremely or very low		Extremely or very light, nothing at all, negligible		Extremely or very easy		Extremely or very low/light, nothing at all, negligible	Acceptable – Negligible risk	No Risk	6
	2 Low		Light		Easy		Low / light	Further Investigation, Change may be needed	Low Risk	
	3 Low to Medium		Moderate somewhat strong, hard, tough or difficult		Moderate or somewhat difficult		Moderate or somewhat heavy, high or strong	Further Investigation (Investigate closely), Change soon	Medium Risk	
	4 Medium									
	5 Medium to High		Strong, hard, tough or difficult		Difficult		Heavy, high or strong	Further Investigation (investigate urgently), implement change	High Risk	
	6 High	X		X		X				
	7 High to Very High		Very strong, hard, tough or difficult		Very difficult		Very heavy, high or strong	Implement Change immediately	Very High risk	
	8 Very High									
	9 Very High to Extremely High		Extremely strong, hard, tough or difficult		Extremely difficult		Extremely heavy, high or strong			
	10 Extremely High									

Indicator	*Respondent's comments*	*Remarks*
	Effort: Hard due to tight space Difficulty: Difficult due to tight space Load/Force: Quite high force to fasten/ unfasten bolts/nuts in tight space	

Figure 1: RAPh's Scale score for rear air bellow replacement process

4.2 Brake disc, brake pad and calliper replacement

The replacement of brake discs, brake pads, and callipers in a bus is considered as a physically demanding job as the bus braking systems are designed to handle heavy loads and frequent stopping, making the components larger, heavier, and more complex. This increases the physical effort required. One of the main challenges in this process is handling heavy components. Brake discs and callipers on buses are significantly heavier than those on passenger cars. Limited working space around the wheel assembly can further complicate removal and installation, especially when dealing with seized bolts, corroded parts, or tight clearances.

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In this replacement activity, worker needs to remove the worn parts in narrow and restricted space. The tasks include to unfasten the bold and nuts and manually remove the calliper or the disc (depending on the task) form the tight wheel area. Two workers required to manually remove the heavy calliper and brake disc. Worker complains difficult situation to handle very heavy calliper or brake disc in restricted space in extreme awkward posture during removal or installation of these parts. The two workers need to be inside the restricted the wheel area (as shown in **Figure 2**) during removal and installation of the calliper. **Figure 2** shows the RAPh's Scale score as responded by the worker. The score given is 7 (Very High Risk).

RAPh's Scale Scoresheet

Task Description	Score	Effort	Difficulty	Load or Force	Action Level	Risk Level	RAPh's Scale Score
Brake disc, brake pad and caliper replacement 	1 Extremely or very low	Extremely or very light, nothing at all, negligible	Extremely or very easy	Extremely or very low/light, nothing at all, negligible	Acceptable – Negligible risk	No Risk	7
	2 Low	Light	Easy	Low / light	Further Investigation, Change may be needed	Low Risk	
	3 Low to Medium	Moderate somewhat strong, hard, tough or difficult	Moderate or somewhat difficult	Moderate or somewhat heavy, high or strong	Further Investigation (Investigate closely), Change soon	Medium Risk	
	4 Medium						
	5 Medium to High	Strong, hard, tough or difficult	Difficult	Heavy, high or strong	Further Investigation (investigate urgently), implement change	High Risk	
	6 High (X)			(X)			
	7 High to Very high	Very strong, hard, tough or difficult	Very difficult (X)	Very heavy, high or strong	Implement Change immediately	Very High risk	
	8 Very high						
	9 Very High to Extremely high	Extremely strong, hard, tough or difficult	Extremely difficult	Extremely heavy, high or strong			
	10 Extremely high						

Indicator	*Respondent's comments*	*Remarks*
	Effort: Hard due to heavy caliper in tight space **Difficulty:** Very Difficult due to tight space to place heavy caliper inside **Load/Force:** High force to lift heavy caliper and place it on the brake disc	

Figure 2: RAPh's Scale score for brake disc, brake pad and calliper replacement process

4.3 Oil sump tank replacement

Oil sump tank replacement in bus maintenance presents significant ergonomic challenges due to the working posture, component weight, confined space, and duration of the task. Workers are often required to work beneath the bus, adopting awkward postures such as prolonged bending, kneeling, squatting, or working with arms raised above shoulder level. These positions increase physical strain on the lower back, neck, shoulders, and knees, raising the risk of musculoskeletal disorders (MSDs) if ergonomic principles are not applied.

The oil sump tank itself is large and heavy with high oil capacity. Manual handling of the sump during removal and installation exposes workers to risks of overexertion, sudden load shifts, and loss of balance. Workers will have to apply excessive force and maintain static postures for extended periods, which eventually contributes to muscle fatigue.

In this replacement activity, two workers need to remove the oil sump tank. The tasks include to unfasten the bold and nuts and manually remove the tank for replacement. Two workers required to manually remove the tank and install new tank. Worker complains difficult situation to handle heavy oil sump tank in extreme awkward posture (arm above shoulder level) during removal and installation as shown in **Figure 3**. **Figure 3** also shows the RAPh's Scale score as responded by the worker. The score given is 6 (High Risk).

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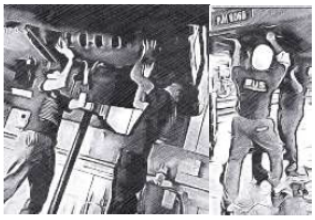
RAPh's Scale Scoresheet

Task Description	Score	Effort	Difficulty	Load or Force	Action Level	Risk Level	RAPh's Scale Score
Oil sump replacement 	1 Extremely or very low	Extremely or very light, nothing at all, negligible	Extremely or very easy	Extremely or very low/light, nothing at all, negligible	Acceptable – Negligible risk	No Risk	6
	2 Low	Light	Easy	Low / light	Further Investigation, Change may be needed	Low Risk	
	3 Low to Medium	Moderate somewhat strong, hard, tough or difficult	Moderate or somewhat difficult	Moderate or somewhat heavy, high or strong	Further Investigation (Investigate closely), Change soon	Medium Risk	
	4 Medium		X				
	5 Medium to High	Strong, hard, tough or difficult	Difficult	Heavy, high or strong	Further Investigation (investigate urgently), implement change	High Risk	
	6 High	X		X			
	7 High to Very high	Very strong, hard, tough or difficult	Very difficult	Very heavy, high or strong	Implement Change immediately	Very High risk	
	8 Very high						
	9 Very High to Extremely high	Extremely strong, hard, tough or difficult	Extremely difficult	Extremely heavy, high or strong			
	10 Extremely high						

Indicator	*Respondent's comments*	*Remarks*
	Effort: Hard due to heavy oil sump tank **Difficulty:** Somewhat Difficult lifting heavy oil sump tank above the head and fasten the bolts/nuts **Load/Force:** High force to lift heavy oil sump tank above the head and fasten the bolts/nuts. Need to hold the oil sump and fasten the bolt/nut	

Figure 3: RAPh's Scale score for oil sump tank replacement process

5. CONCLUSION

In conclusion, RAPh's Scale demonstrate that it can be used to assess physical work activities. Based on the feedback from respondents, they are able to describe their feeling of intensity during the task being in performed by using this scale.

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	1 Extremely or very low	Extremely or very light, nothing at all, negligible	Extremely or very easy	Extremely or very low/light, nothing at all, negligible	Acceptable – Negligible risk	No Risk	
	2 Low	Light	Easy	Low / light	Further Investigation, Change may be needed	Low Risk	
	3 Low to Medium	Moderate somewhat strong, hard, tough or difficult	Moderate or somewhat difficult	Moderate or somewhat heavy, high or strong	Further Investigation (Investigate closely), Change soon	Medium Risk	
	4 Medium						
	5 Medium to High	Strong, hard, tough or difficult	Difficult	Heavy, high or strong	Further Investigation (investigate urgently), implement change	High Risk	
	6 High						
	7 High to Very high	Very strong, hard, tough or difficult	Very difficult	Very heavy, high or strong	Implement Change immediately	Very High risk	
	8 Very high						
	9 Very High to Extremely high	Extremely strong, hard, tough or difficult	Extremely difficult	Extremely heavy, high or strong			
	10 Extremely high						

Indicator	*Respondent's comments*	*Remarks*
	Effort: Difficulty: Load/Force:	

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