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# Rate of Perceived Exertion of Female Aviation Workers Pertaining to Selected Aviation Workspace and Recommended Fitness Regime to Reduce Exertion

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**Abstract.** In aviation maintenance, workers usually work in tight spaces to maintain or repair aircraft. These constricted spaces provide uncomfortable feeling to these workers and in return the workmanship of the workers declined in terms of quality and thus affect the safety of the aircraft. However, some workers are fit enough to go through these conditions without hassle or without much pain. This paper focused upon female aviation workers and collected data on their rate of perceived exertion pertaining to two selected aviation workspaces. The data and analyses showed that those who are fit felt less exertion while those who are not fit felt more exertion. This paper then recommended several physical exercises to increase their fitness and in turn reduce the exertion felt.

## 1. Introduction

The aviation world involves around safety where safety is the uttermost important. In the field of aircraft maintenance, aviation workers indulge in hours of works fixing and maintaining fleets of aircrafts. Those who are fit and are not subjected to rigorous situation would produce optimum results maintaining the aircraft. Work outputs which are mediocre or bad would compromise the safety of the aircrafts and plausibly lead to accidents or incidents.

Aircraft Maintenance Textbook authored by Federal Aviation Administration (FAA) stated that 80% of aircraft accidents were due to human factors [1]. The handbook goes further by stating that “not conducive” working environment is a contribution to stress which also one of the attributes of human factors [2]. While “not conducive” working environment such as tight spaces in an aircraft is hard to eliminate, the stress value associated with it could be reduced if one is fit. A fit person with certain muscle mass (for example at the legs) and optimum body weight could withstand kneeling, for say around 30 seconds, to fix an aircraft component at a tight space.

In this paper we had chosen two working conditions which were likely causes of stress for maintenance workers. Our respondents or test subjects are female students of aviation maintenance studying at Universiti Kuala Lumpur Malaysian Institute of Aviation Technology (UniKL MIAT). These students, in their course of the aviation maintenance programme, had gone through numerous



practicals (tight and open spaces) in fixing or maintaining aircraft. This paper recorded their RPE (Rate of Perceived Exertion) which indicates the level of their stress, actuate analysis upon these RPE, and recommended appropriate physical exercise to decrease these RPE levels.

## **2. Literature Review of Rate of Perceived Exertion (RPE)**

The United State Health Department stated that RPE is a tool that could measure the intensity of a physical activity [3]. Perceived Exertion is a feeling that one get whether it is easy or hard, depending upon one's fitness and the gravity of the physical activity. The feeling encompasses heart rate, perspiration, fatigue of muscle, and breathing rate.

RPE is based upon one's perception, thus is it subjective. But the US Health Department reiterated that it still provides a good measure of one's capability. RPE was invented by Gunnar Borg of University of Stockholm. Borg's intention was to quantify one's strain or aches and this is done using a scale [4]. This scale provides a tool for comparison, regardless of gender, age, race, and others.

Borg acknowledged that there's a drawback in making comparison between individuals but this drawback is countered by categorizing the scale with categories such as "Nothing at all", "Very very weak", "Very weak", "Weak", "Moderate", "Somewhat strong", "Strong", "Very Strong", and "Very very strong". There exist in the variation of the scale in terms of the terminologies used in the categorization but the basis is the same. The RPE scale that's used in this paper is based upon the Cleveland Clinic in the United States with a ranging from 0 till 10 (0 being the most easiest and 10 being the most hardest)

Borg further explained that the scale could also be used to rate one's difficulties in breathing. This is quite interesting as maintenance workers, in the author's opinion based upon heuristic, who are subjected to intense working condition such as tight space reported slight changes in their breathing rate. According to a report by Kane from the United States Air Force, there is a need to measure an employees stress level in lieu with their working conditions and investigation upon their perceptions, through RPE, is one way to gauge stress level [5]. Kane recommended that employees to be "conditioned" (via physical exercise) to allow them to cope or decrease their stress level and thus increase safety [5].

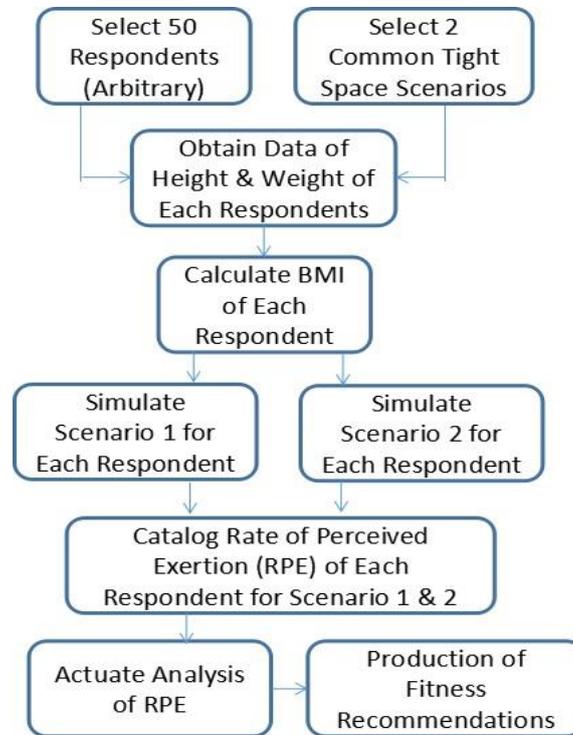
## **3. Methodology**

The methodology of this project is shown in Figure 1. 50 respondents which are students from UniKL MIAT were chosen. The chosen subjects were all females and chosen randomly. The scope of this project is confined only for females as they are a minority in the first line aviation maintenance workforce. According to Clark, only 2.3% of the certified aircraft mechanic workforce in the United States are women [6]. The author is interested on how the female workers fare in their roles, in terms of fitness and workplace exertion (strain), thus the existence of this project.

Two scenarios of aircraft maintenance activity were selected where these two activities are performed at tight spaces. Its a norm that avionics rack in an aircraft is located at the cargo bay of the aircraft and workers need to transverse tight spaces in order to actuate maintenance upon the rack. Workers are then required to kneel or sit in order to tinker upon the rack. Thus the two scenarios used in this project are : "Kneeling for 8 Seconds" (Scenario 1) and "Crawling a Distance of 2 Meters" (Scenario 2).

The crawling of 2 meters is based upon the exact length that one has to transverse in the Boeing 727 in order to gain access to the avionics rack [7]. For other mid size aircrafts the crawling length is roughly similar. As for kneeling for 8 seconds it was based upon real life maintenance works upon avionics rack of the Boeing 727 where rough measurements of the duration of the workers kneeling

was taken by the author. To gain realism, the two scenarios of this project were actuated at the avionics rack located at the cargo bay of the Boeing 727 that's currently parked at UniKL MIAT.



**Figure 1.** The Methodology of the Project

Each respondent was measured in terms of height (meter) and weight (kg). A measuring tape was used to measure the height and a digital scale was used to measure the weight. Using equation (1), the Body Mass Index (BMI) of each respondent was calculated.

$$BMI = Weight (kg) / [Height (m) * Height (m)] \quad (1)$$

Then, Scenario 1 was simulated for each respondent. After the end of Scenario 1, each respondent was asked to rate the exertion that she had encountered using the RPE scale shown in Figure 2 (this RPE scale was taken from the notes of Eric Kim) [8]. These were then repeated for Scenario 2.



**Figure 2.** The RPE Scale that Was Used

The rated exertions of each respondent for each scenario were then recorded and cataloged in an excel spreadsheet. Analysis and calculation were then actuated from these data. The analysis and calculation are:

1. Average RPE for Situation 1
2. Average RPE for Situation 2
3. 2D Graphical Trend of RPE Situation 1
4. 2D Graphical Trend of RPE Situation 2
5. The Frequency of RPE Values for Situation 1
6. The Frequency of RPE Values for Situation 2
7. Distribution of Respondents in Terms of BMI Values.

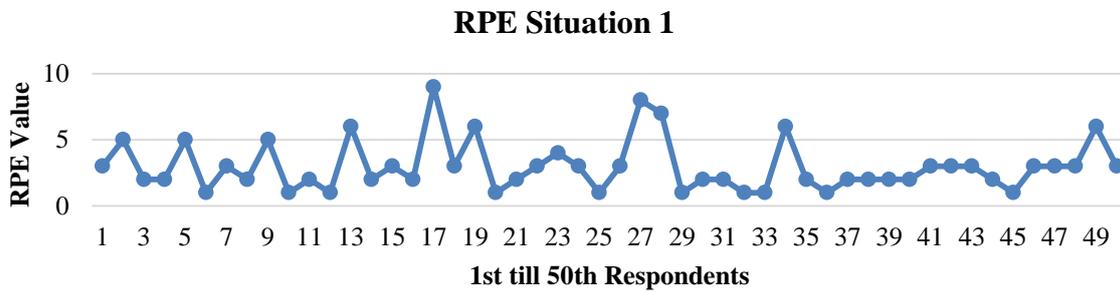
The final step was to give recommendations in terms of physical exercise in order to decrease the RPE values of respondents. The recommendations were based upon the analysis of the RPE and the recommended appropriate exercises were based upon literature review or best practices in fitness regime.



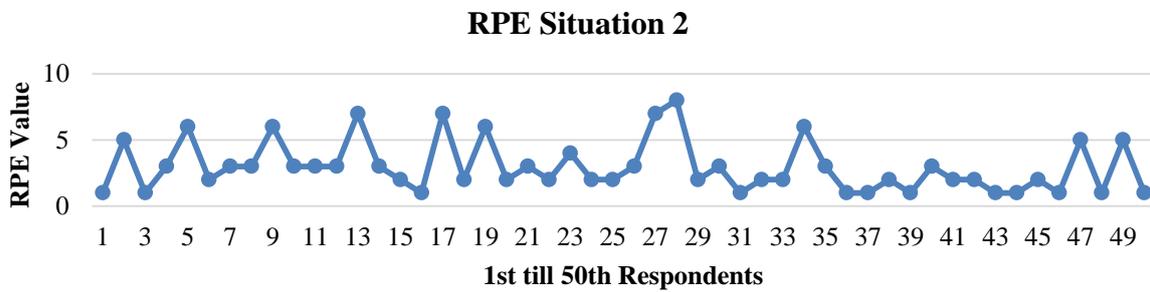
**Figure 3.** Tight Spaces where Aviation Workers need to Kneel and Crawl in Order to Maintain Aircraft Components

#### 4. Results

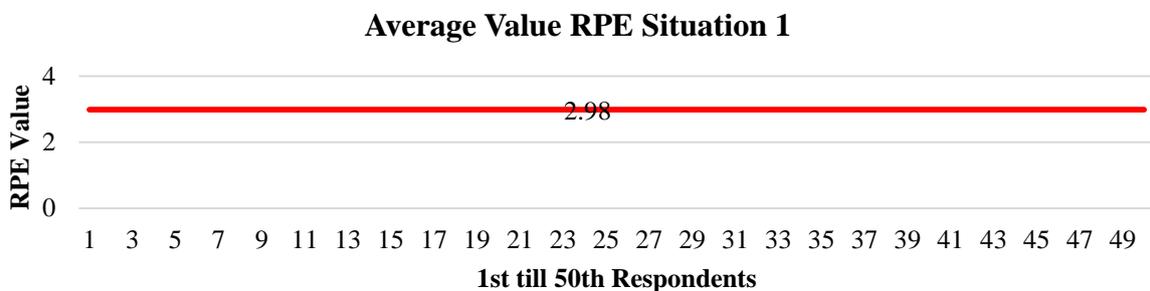
Figure 4 shows the RPE values among 50 respondents pertaining to Situation 1. The RPE values among respondents are mixed with high, middle, and low values. Meanwhile Figure 5 shows the RPE values among 50 respondents pertaining to Situation 2. The RPE values among respondents are also mixed with high, middle, and low values. Figure 6 shows the average value of RPE pertaining to Situation 1. Figure 7 shows the average value of RPE pertaining to Situation 2. Figure 8 shows the frequency of RPE values pertaining to Situation 1. Figure 9 shows the frequency of RPE values pertaining to Situation 2. Figure 10 shows the distribution of respondents in terms of BMI values.



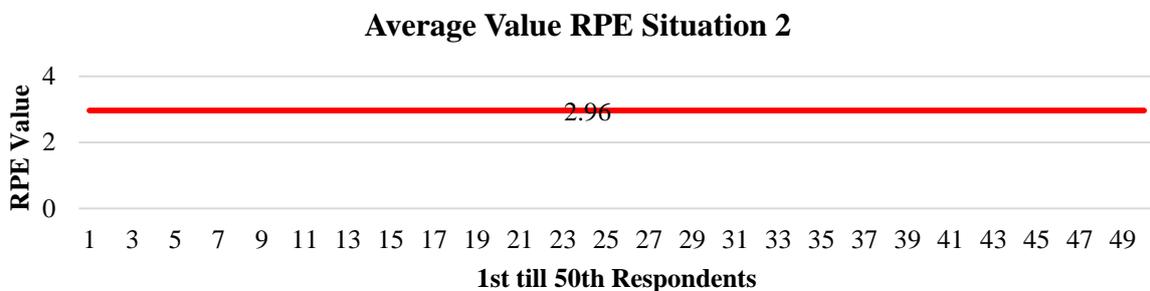
**Figure 4.** RPE for Situation 1



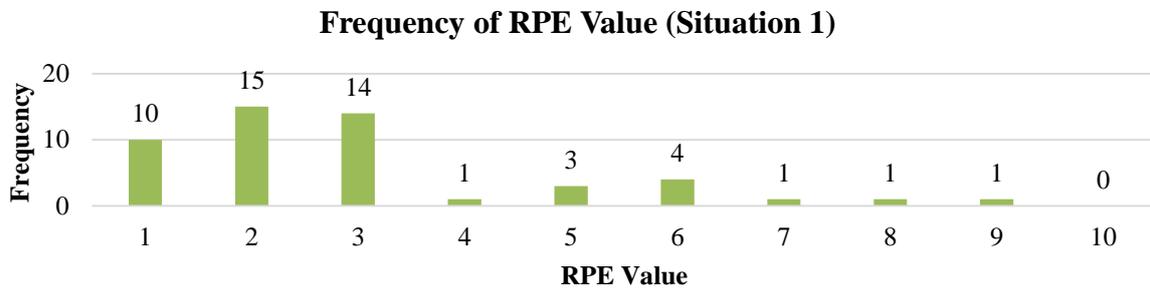
**Figure 5.** RPE for Situation 2



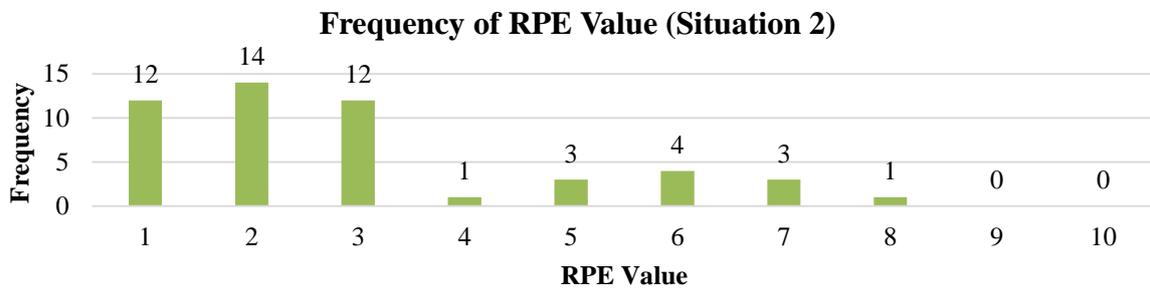
**Figure 6.** Average Value of RPE pertaining to Situation 1



**Figure 7.** Average Value of RPE pertaining to Situation 2

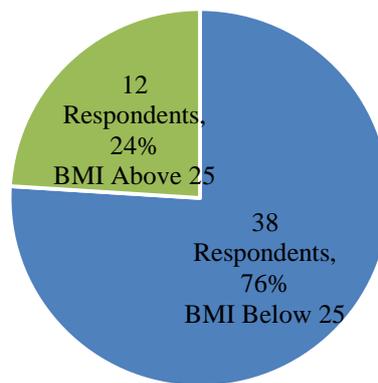


**Figure 8.** Frequency of RPE values pertaining to Situation 1



**Figure 9.** Frequency of RPE values pertaining to Situation 2

**Distribution of Respondents in terms of BMI Value**



**Figure 10.** Distribution of Respondents in terms of BMI Values

**5. Analysis of Results and Discussion**

Pertaining to Figure 4, we can observe that the respondents gave mixed reactions with the highest RPE being 9 and the lowest RPE being 1. Situation 1, which is kneeling for 8 seconds, was deemed Really Really Hard by 1 respondent, as shown in Figure 8. This 1 respondent was respondent number 17. Peering the data sheet, the BMI for this respondent was 29.4758. According to the BMI Scale, a value of 25 above (for female) is considered overweight and obese. It is not surprising that this 1 respondent

has a BMI value of above 25 and thus this “overweight” contributed to her feeling or perceiving that Situation 1 was Really Really Hard.

Situation 1 was deemed Really Easy by 10 respondents, as shown in Figure 8. Peering the data sheet, the BMI for these respondents were below the value of 25. According to the BMI Scale, a value below 25 (for female) is considered healthy weight. This healthy weight may have contributed to them feeling or perceiving that Situation 1 was Really Easy.

Looking at the RPE Scale from Figure 2, the “hard” category starts from RPE value of 4 (sort of hard) till 10 (maximal). We are interested to observe how many respondent perceive Situation 1 as “sort of hard” till “maximal”. Peering at Figure 8, 11 respondents had indicated that Situation 1 is hard (ranging from sort of hard till maximal). That’s 22% out of the total respondents. We were interested to know whether these 11 respondents have BMI above 25 or not. Peering at the excel sheet, all of the 11 respondents indicated above have BMI above 25.

Looking at the RPE Scale from Figure 2, the “easy” category starts from RPE value of 0 (rest) till 3 (moderate). We are interested to observe how many respondent perceive Situation 1 as “rest” till “moderate”. Peering at Figure 8, 39 respondents had indicated that Situation 1 is easy (ranging from rest till moderate). That’s 78% out of the total respondents. We were interested to know whether these 39 respondents have BMI below 25 or not. Peering at the excel sheet, 38 respondents indicated above have BMI below 25 while only 1 has a BMI above 25 (the BMI value of this one respondent is 25.711).

Pertaining to Figure 5, we can observe that the respondents gave mixed reactions with the highest RPE being 8 and the lowest RPE being 1. Situation 2, which is crawling a distance of 2 meters, was deemed Really Hard by 1 respondent, as shown in Figure 9. This 1 respondent was respondent number 28. Peering the data sheet, the BMI for this respondent was 26.3702. According to the BMI Scale, a value of 25 above (for female) is considered overweight and obese. It is not surprising that this 1 respondent have a BMI value of above 25 and thus this “overweight” contributed to her feeling or perceiving that Situation 2 was Really Hard.

Situation 2 was deemed Really Easy by 12 respondents, as shown in Figure 9. Peering the data sheet, the BMI for these 12 respondents were between 19 till 24.5603. According to the BMI Scale, a value between 19 and 24.5603 (for female) is considered healthy weight. This healthy weight may have contributed to them feeling or perceiving that Situation 2 was Really Easy.

Again looking at the RPE Scale from Figure 2, the “hard” category starts from RPE value of 4 (sort of hard) till 10 (maximal). We are interested to observe how many respondent perceive Situation 2 as “sort of hard” till “maximal”. Peering at Figure 9, 12 respondents had indicated that Situation 2 is hard (ranging from sort of hard till maximal). That’s 24% out of the total respondents. We were interested to know whether these 12 respondents have BMI above 25 or not. Peering at the excel sheet, all 12 respondents have BMI above 25.

Looking at the RPE Scale from Figure 2, the “easy” category starts from RPE value of 0 (rest) till 3 (moderate). We are interested to observe how many respondent perceive Situation 2 as “rest” till “moderate”. Peering at Figure 9, 38 respondents had indicated that Situation 2 is easy (ranging from rest till moderate). That’s 75% out of the total respondents. We were interested to know whether these 38 respondents have BMI below 25 or not. Peering at the excel sheet, all of the 38 respondents indicated above have BMI below 25.

Situation 2 seems to be just slightly harder to the respondents in comparison to Situation 1 based upon the fact that 24% of the respondents indicated Situation 2 as hard as compared to 22% of the respondents which indicated Situation 1 as hard. On average Situation 1 has an RPE of 2.98 which falls in the category of easy. This indicates Situation 1 is still a favorable working condition but it is

advisable for the respondents that perceived it as hard to go through recommended physical exercises to reduce the strains they encountered during Situation 1.

On average Situation 2 has an RPE of 2.96 which falls in the category of easy. This indicates Situation 2 is also still a favorable working condition but its advisable for the respondents that perceived it as hard to go through recommended physical exercises to reduce the strains they encountered during Situation 2.

24% of the respondents have unhealthy BMI which is slightly alarming as maintenance crews have to work in tight spaces most of the time. Hence actuating the recommended physical exercises would reduce their BMI to a range which is lower than 25.

A majority of respondents deemed Situation 1 and 2 as easy (78% and 75% respectively) which is good in terms of workers output as a worker which is in a environment which is not strenuous would produce optimum results.

## 6. Recommended Physical Exercises

Situation 1 which is kneeling for 8 seconds and Situation 2 which is crawling a distance of 2 meters require an individual to press the knee caps onto the floor for a stipulated duration of time (for kneeling) and move the knees at a distance (crawling). This requires the individual to have strong knees and there are several exercises which focuses upon the knees. Based upon the data collected and analysis of the results, its recommended, though not compulsory, that those with BMI above 25 to lose weight first before actuating the knees exercise. This is to prevent strain upon the knees as those with excessive weight would induce high amount of forces upon the knees.

One such way to decrease the BMI is through the implementation of High Intensity Interval Training (HIIT). HIIT program requires the individual to go through short intense exercise with short rest in between. And this cycle is repeated several time where the total duration is usually less than 30 minutes. Below is a typical HIIT program based upon the basis from Stoppani [9].

1. Sprint with 100% high intensity for 15 seconds
2. Rest or walk for 60 seconds
3. Repeat the cycle above another 10 times
4. Last Sprint with 100% high intensity for 15 seconds
5. Total Time of the above program is 14 minutes

The above program should be implemented for 2 till 3 weeks depending upon the outcome of the program. If weight loss is not imminent, extend the duration till 4 weeks or more. The design of the program is not rigid with extension allowable.

Individuals with BMI below 25 or those that already done HIIT and had achieved BMI less than 25 should then proceed to the knees exercise. Below are basic knees exercises which strengthen the muscle around the knee joints which in turn decreases stress upon the knees (this prevents injuries to the knees as well) [10].

To actuate Partial Squats, one has to stand about 12 inches away from the front chair with one's feet about hip-width apart and toes forward (look at Figure 11). Bending at the hips, one has to slowly lower one's self halfway down to the chair. One has to keep one abs tight and ensure the knees are behind the toes. Then lift oneself up again. One has to actuate this 10 till 12 repetitions and 3 sets till 4 sets with around 2 till 4 minutes rest in between set. It is advisable for one to actuate this exercise 2 or 3 times a week.

Another knee exercise that could be actuated is the Step-Ups as shown in Figure 12. Using an Aerobic Step Bench or a staircase, one has to step up onto the step with one's right foot. One's left foot is then tap on the top of the step and then lower it down on the floor. As one step up, the knee

should be directly over the ankle. The process is then repeated for the left foot. One has to actuate this 10 till 12 repetitions and 3 sets till 4 sets with around 2 till 4 minutes rest in between set. It is advisable for one to actuate this exercise 2 or 3 times a week.



**Figure 11.** Partial Squats



**Figure 12.** Step-Ups

Another knee exercise which is good for strengthening the knees is the Calf Raises. This is shown in Figure 13. Using a chair or wall for balance, one stand with one's feet about hip width apart and toes straight ahead. Then one slowly lift one's heels off the floor, rising up onto one's toes. Hold this position and then lower back to the floor. One has to actuate this 10 till 12 repetitions and 3 sets till 4 sets with around 2 till 4 minutes rest in between set. It is advisable for one to actuate this exercise 2 or 3 times a week.



**Figure 13.** Calf Raises

## 7. Conclusion

It is imperative that workers in the aviation field are fit as their fitness would influence the outcome of their work. As shown in the data collected, workers (respondents) that have healthy BMI have less exertion imparted on them making them "comfortable" during the actuation of their jobs. This perhaps would make them produce optimum results in their work, thus improving safety.

Analysis of the data also showed only a marginal percentage (22% and 24%) of the workforce (respondents) had a hard time actuating the simulated maintenance task. And data shown that these percentage had a hard time due to their unhealthy BMI.

The author had recommended several concentrated exercises to be actuated by all workers in order for them to retain fitness or to increase their fitness (at the same time lower their BMI to acceptable level). These prescribed exercises are based upon the data collected which indicates concentration should be upon the surrounding muscle of the knees. Overall, the situation is not alarming as a majority of the sampled aviation workers (78% and 75% respondents) had an easy time actuating the simulated maintenance task.

The author opinionated that there is room for improvement in terms of workers fitness and we do hope the recommended exercises could increase their fitness and thus produce optimum work. The author currently in the midst of collecting data of the fitness level of these workers after they had gone through the prescribed exercises.

## 8. Acknowledgment

The author would like to acknowledge the contribution of the respondents (aviation students of UniKL MIAT) in participating in this project.

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