Second Semester Examination
2023/2024 Academic Session

July / August 2024

EME 442 – Biomechanics
(Biomekanik)

Duration: 2 hours
(Masa: 2 Jam)

Please check that this examination paper consists of ELEVEN (11) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS (11) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FOUR (4)** questions.

*[**Arahan**: Jawab **EMPAT (4)** soalan]*

1. (a) Work-related Musculoskeletal Disorders (WMSDs) encompass a range of conditions that impact movement and musculoskeletal systems of individuals within a workplace setting. To address and prevent such issues, the Ovako Working-posture Assessment System (OWAS) is one of the widely used method for evaluating working postures and improving workplace health. Referring to the guidelines in **Appendix 1**, determine the OWAS scores for the postures of the workers shown in **Figure 1 (a). State the <u>assumptions</u> you made for this calculation.**

A worker is using a 3kW handheld concrete saw, which weighs 10 kg, to cut through concrete.

A farmworker is bending down to plant rice seedlings in a vast paddy field.

Two emergency medical service personnel are lifting a 130 kg person who has fallen to the floor.

Determine the OWAS score for the posture of the worker indicated with an arrow.

Figure 1 (a) – Typical awkward postures in working activities.

(30 marks)

(b) A worker lifts 15 kg packages from the bottom shelf (origin) and transfers them to the second shelf (destination), as depicted in Figure 1 (b).

This task is repeated ten times per hour.

(i) Evaluate the six components of numeric multiplier factors. Equations and tables for multipliers are provided in **Appendix 2.**

(10 marks)

(ii) Using the National Institute of Occupational Safety and Health (NIOSH) revised lifting equation, determine the recommended weight limit (RWL) and lifting index (LI) for both the origin and destination of this specific task.

(30 marks)

(iii) Provide detailed recommendations on how to optimize the lifting process to improve the LI and reduce the risk of injury.

(30 marks)

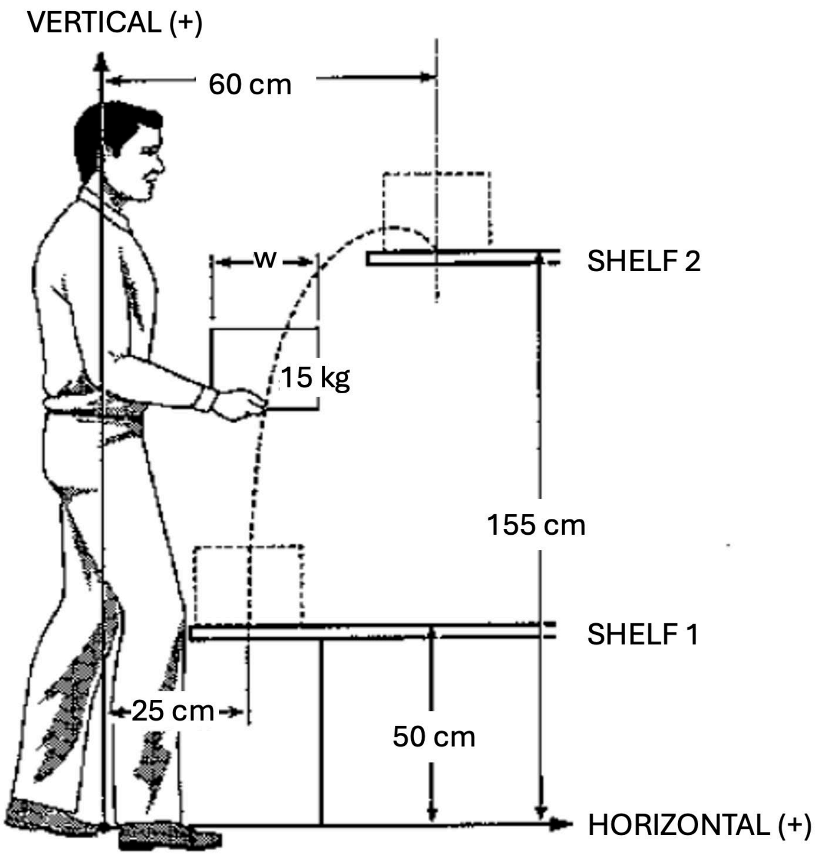

Figure 1 (b) – Worker loading packages on the upper shelf.

2. (a) A woman, aged 65, lifts an object with a mass of 10 kg using two different lifting methods. At one point in time, these methods result in the body posture shown in [Figure 2 (a)]. Her head, arms, and trunk collectively weigh 60 kg. Determine the following:

(i) Calculate the force exerted by the erector spinae muscle, F_M, during the lifting task for the two different body postures.

(10 marks)

(ii) Determine the compressive and shear components of joint reaction force (F_{JC} and F_{JS} respectively) at the L5/S1 lumbar disc vertebral joint (indicated by the grey square), point O, during the lifting task for the two different body postures.

(10 marks)

(iii) Based on your answer (ii), compare the calculated forces of joint compression (F_{JC}) for the two different body postures to the recommended value of 3400 N, which serves as a guideline set by NIOSH to determine a safe threshold for the amount of force that can be applied to joints during task performance. Provide suggestions to minimize the risk of injury and perform the task safely.

(20 marks)

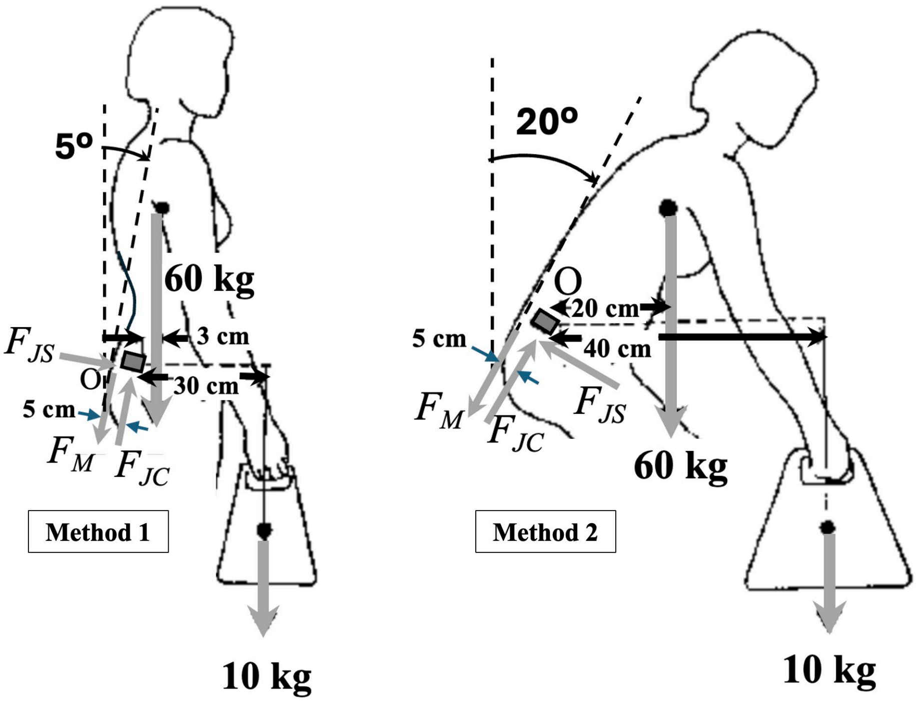

Figure 2 (a) – The woman is lifting 10 kg object using two different lifting methods.

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(b) A group of final-year mechanical engineering students from Universiti Sains Malaysia (USM), studying biomechanics, has developed a functional prototype of an exercise machine aimed at enhancing lower-limb coordination and muscle strength in post-stroke patients.

To evaluate the effectiveness of the machine, the team plans to conduct clinical trials at Hospital Universiti Sains Malaysia (HUSM), involving 30 post-stroke patients. These patients will be randomly divided into two groups: the manual physical therapy group (control group) and the machine-aided therapy group (the machine group).

The main aim of the study is to explore whether the assistive machine in therapy could lead to better recovery outcomes compared to traditional physical therapy.

(i) State the specific inclusion and exclusion criteria that would be appropriate for selecting participants in the clinical trial.

(20 marks)

(ii) Describe the ethical considerations and rights of participants before, during and after their involvement in the study.

(20 marks)

(iii) Suggest **THREE** potential methods that can be used to collect biomechanical data during the clinical study to analyze the effect of the exercise machine on lower limb in post-stroke patients.

(20 marks)

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3. A WREX orthosis as shown in Figure 3 below can be used to support children with neuromuscular diseases where the hands are relatively weak.

   (a) The primary function of WREX is to support the static weight of the hand and arm. Explain how this is achieved with the help of sketches the basic mechanism of WREX preferably using parallelogram.

   (40 marks)

   (b) One important feature of the orthosis is the ability to cater for different length, weight and muscle strength of the patient. Discuss how this can be achieved in the design.

   (30 marks)

   (c) One of the measures for the weakness of the muscle is the manual muscle test (MMT) – explain how the result from the manual muscle test influences the WREX design.

   (30 marks)

Figure 3 – A WREX orthosis.

4. You have developed a device to help nurses to lift patients named **NEAR1**. You are planning a clinical trial to determine the efficacy of the intervention. In order to prove that **NEAR1** is better than the existing lifting device called **LIFTER**. For the clinical trial the statistical parameters that are accepted are ($p < 0.05$), Power=0.8. The data from the pilot study (N=10) is listed in **Table 4 (i)** below. The important criterion is the lumbar compression force. The population standard deviation can be taken as 320N. **Table 4 (ii)** is the for power-standardized difference.

   The clinically important difference that we want to detect is 200N.

   (a) Determine the standardized difference and the sample size required to achieve the above power value.

   (40 marks)

   (b) Comment on the power value P=0.8 used. Is this sufficient? Would you advise the study to go for P=0.95?

   (20 marks)

   (c) What is the implication when P=0.95 is used in terms of costs and time needed to complete the study?

   (20 marks)

   (d) Most study requires the analysis to include the confidence interval on top of the p-value. Do you agree with this requirement and explain the reason for it?

   (20 marks)

Table 4 (i) – Data from pilot study

Task	NEAR1	LIFTER	Control
Mean lumbar compression force (Newton)	2750	3050	3300
Standard deviation of the lumbar compression force (Newton)	150	200	220

Table 4 (ii) – Power level - standardized difference

	Power level (pβ)			
Sdiff	**0.99**	**0.95**	**0.90**	**0.80**
0.10	3676	2600	2103	1571
0.20	920	651	527	394
0.30	410	290	235	176
0.40	231	164	133	100
0.50	148	105	86	64
0.60	104	74	60	45
0.70	76	54	44	33
0.80	59	42	34	26
0.90	47	34	27	21
1.00	38	27	22	17
1.10	32	23	19	14
1.20	27	20	16	12
1.30	23	17	14	11
1.40	20	15	12	9
1.50	18	13	11	8

Sdiff, standardised difference.

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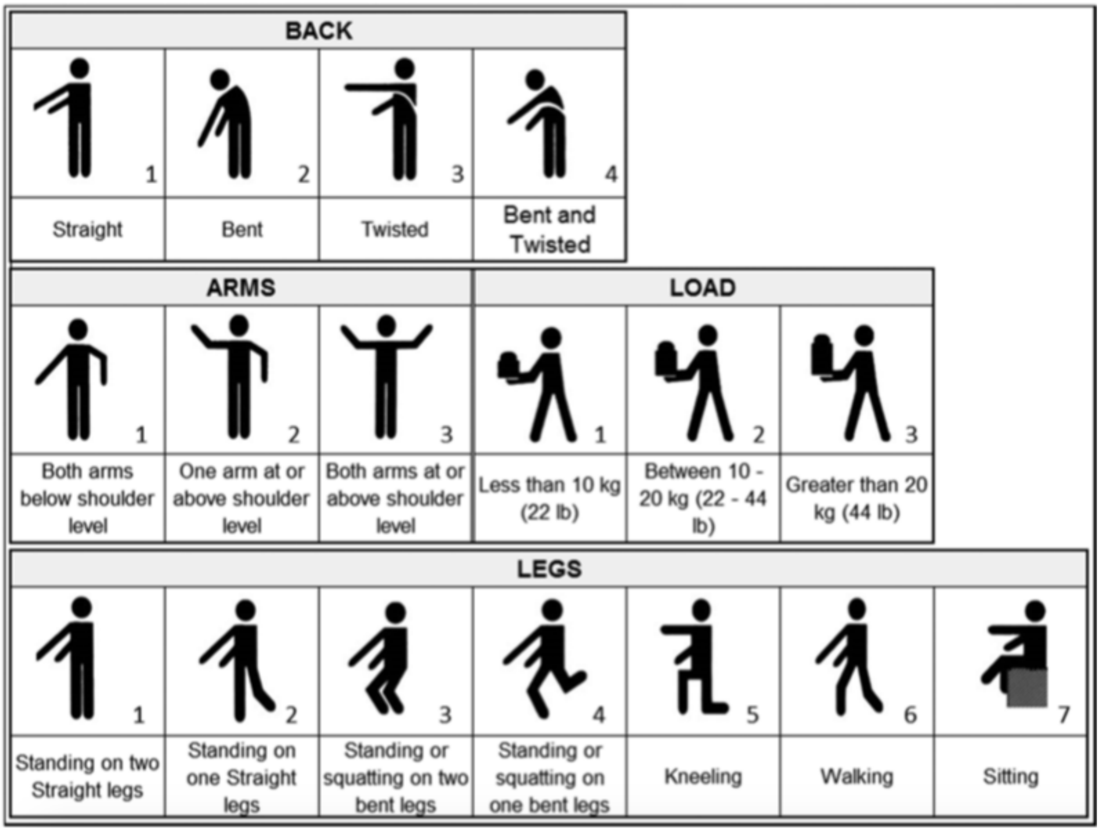
APPENDIX 1

OWAS method postures chart



Postures classification by the combination of variables

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Loads
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1	
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

APPENDIX 2

RWL = LC (51) x HM x VM x DM x AM x FM x CM

		METRIC	US Customary
Load Constant	LC	23kg	51lb
Horizontal Multiplier	HM	25/H	10/H
Vertical Multiplier	VM	1 – (0.003 [V-75])	1 – (0.0075 [V-30])
Distance Multiplier	DM	0.82 + (4.5 / D)	0.82 + (1.8 / D)
Asymmetric Multiplier	AM	1 – (0.0032 A)	1 – (0.0032 A)
Frequency Multiplier	FM	refer table	refer table
Coupling Multiplier	CM	refer table	refer table

H,V and D measured in inches or centimeters

Frequency Multiplier table (FM)

Frequency lift/min (F)*	Work duration					
	≤1 Hour		>1 ≤2 Hours		>2 but ≤8 Hours	
	V < 30 inches	V ≥ 30 inches	V < 30 inches	V ≥ 30 inches	V < 30 inches	V ≥ 30 inches
≤0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

*For lifting less frequency than once per 5 minutes, set F = 0.2 lifts/minute; Application manual for the revised NIOSH lifting equation, 1994 [2].

Coupling Multiplier table (CM)

Coupling Type	Coupling Multiplier V < 30 inches (75 cm)	V >= 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Hand-to-Container Coupling Classification

GOOD	FAIR	POOR
For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object	For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees	Lifting non-rigid bags (i.e., bags that sag in the middle).