

Article

Energy Expenditure during Acute Weight Training Exercises in Healthy Participants: A Preliminary Study

Muhammad Adeel ^{1,2}, Chien-Hung Lai ^{3,4}, Chun-Wei Wu ², Jiunn-Horng Kang ^{3,4}, Jian-Chiun Liou ², Hung-Chou Chen ^{3,5} , Meng-Jyun Hong ² and Chih-Wei Peng ^{1,2,6,*} 

¹ International PhD Program in Biomedical Engineering, College of Biomedical Engineering, Taipei Medical University, Taipei 110, Taiwan; d845108004@tmu.edu.tw

² School of Biomedical Engineering, College of Biomedical Engineering, Taipei Medical University, Taipei 110, Taiwan; george.jasonbiolab@gmail.com (C.-W.W.); jcliou@tmu.edu.tw (J.-C.L.); b812107003@tmu.edu.tw (M.-J.H.)

³ Department of Physical Medicine and Rehabilitation, School of Medicine, College of Medicine, Taipei Medical University, Taipei 110, Taiwan; chlai@tmu.edu.tw (C.-H.L.); jhk@tmu.edu.tw (J.-H.K.); 10462@s.tmu.edu.tw (H.-C.C.)

⁴ Department of Physical Medicine and Rehabilitation, Taipei Medical University Hospital, Taipei 110, Taiwan

⁵ Department of Physical Medicine and Rehabilitation, Shuang Ho Hospital, Taipei Medical University, New Taipei City 235, Taiwan

⁶ School of Gerontology Health Management, College of Nursing, Taipei Medical University, Taipei 110, Taiwan

* Correspondence: cwpeng@tmu.edu.tw; Tel./Fax: +886-2-2736-1661 (ext. 3070)



Citation: Adeel, M.; Lai, C.-H.; Wu, C.-W.; Kang, J.-H.; Liou, J.-C.; Chen, H.-C.; Hong, M.-J.; Peng, C.-W. Energy Expenditure during Acute Weight Training Exercises in Healthy Participants: A Preliminary Study. *Appl. Sci.* **2021**, *11*, 6687. <https://doi.org/10.3390/app11156687>

Academic Editors: Alessandra Durazzo and Wojciech Kolanowski

Received: 5 June 2021

Accepted: 19 July 2021

Published: 21 July 2021

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Abstract: Energy expenditure during weight training exercises produces great fitness and health benefits for humans, but few studies have investigated energy expenditure directly during weight training. Therefore, in this study, we aimed to determine energy costs during three training sessions consisting of three different exercises. Ten participants were randomly allocated into two groups: an untrained ($n = 5$, with no weight training experience) and a trained group ($n = 5$, with some weight training experience). Each participant completed three training sessions on separate days. While wearing a mask for indirect calorimetric measurements, each participant participated in training sessions conducted with three dumbbell exercises: the bent-over row, deadlift, and lunge. Metabolic equivalents (METs), energy expenditure (EE), respiratory exchange ratio (RER), heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and rate of perceived exertion (RPE) were measured. The total energy cost was calculated from the oxygen consumption (VO_2) during each exercise. Our results showed that the METs of a single training session were 3.3 for the untrained group and 3.4 for the trained group, while the sum of the EE was 683–688 and 779–840 kcal, respectively. The physiological parameters, such as heart rate ($p = 0.001$ *) for the lunge and rate of perceived exertion ($p = 0.005$ *) for the bent-over row, changed significantly in both groups. It was concluded that the exercise protocol of this study involved a moderate intensity of 2.4–3.9 METs. The energy cost of each training exercise was between 179 and 291 kcal.

Keywords: weight training; acute exercises; METs; energy expenditure

1. Introduction

Weight training is an important type of exercise for the elderly, general, and athletic populations and is used to enhance body composition along with other aspects of health and performance [1,2]. More specifically, it can reduce body fat, lower blood pressure, enhance cholesterol levels, promote glycemic control, and generally decrease the risk of heart disease [3,4]. As weight training is included as one of the main exercise programs to increase energy expenditure (EE), it should target the large major muscle groups [4–6]. The recommended dose of weight training exercise for a healthy life for all age groups is two or more days per week [4].

Total EE (TEE) is composed of the basal metabolic rate (BMR or basal EE (BEE)) and is equivalent to approximately 60–75% of TEE, activity EE (AEE) is about 15–30% of TEE, and dietary thermogenesis is about 10% of TEE [7,8]. TEE, BEE, and AEE vary over time and differ between sexes, with values for males often higher than those of females, and values for older people are lower than those for younger people [9]. Different disease conditions may have an effect on TEE and AEE [10]. In addition, since the AEE is the most variable component of TEE, it is often used to assess TEE [11–13]. Doubly labeled water is the gold standard to assess TEE because of its high degree of accuracy, and indirect calorimetry is commonly used to track EE in healthy and diseased people over time [14] during physical activity.

The metabolic equivalent (MET) is a functional unit of oxygen consumption during exercise [15–17]. According to the Centers for Disease Control and Prevention (CDC)/American College of Sports Medicine (ACSM) and the Compendium of Physical Activities, 1.6–2.9 METs is considered light intensity, 3.0–5.9 METs is considered moderate intensity, and >6.0 METs is considered vigorous intensity of aerobic exercise [1,18]. Resistance training (RT) is described as 3.5 METs (code 02054) and/or 5.0 METs (code 02052) in the Compendium of Physical Activities [18], with EE ranging from 5 to 10 kcal/min (for men of an average height and weight, this is equivalent to 135–270 kcal). Previous research [15–17] focused on RT using a training machine and/or free weights with high loads. Moderate-intensity exercises using dumbbells, such as the bent-over row, deadlift, and lunge can be performed as free weight exercises.

In the previous literature, many studies have reported the EE of acute or chronic resistance exercise, but to our best knowledge, no study has compared energy costs and physiological profiles of the dumbbell bent-over row, deadlift, and lunge exercises together with rest intervals in one training session. As these exercises use multiple groups of large muscles in the upper and lower body, they may provide benefits of fitness and muscle gain. In addition, this study focused on healthy individuals' weight training so that EEs could be compared between two populations of naive and experienced weightlifters to generalize the study findings for healthy and athletic populations. In RT, pulling or pushing is usually performed rapidly, but in this study, the same speed of 2 s was used for the pulling and pushing phases. In addition, dumbbells serve as free weights with a higher degree of freedom and increased challenge to exercised muscles. Therefore, the main objectives of this study were twofold: (1) to compare the energy cost of each weight training exercise (the dumbbell bent-over row, deadlift, and lunge) between the two groups to determine if the exercises belong to moderate or high intensity at 60% of one-repetition maximum (RM) loading and (2) to compare physiological parameters during these three weight training exercises. The results of this study can be used to determine an exercise protocol that can be utilized for fitness and conditioning purposes in healthy populations.

2. Materials and Methods

Participant Recruitment: A single-blinded controlled study was conducted at Taipei Medical University Hospital, and the protocol was approved by the TMU Joint Institutional Review Board (IRB no.: N202004023). The trial was registered at [ClinicalTrials.gov](https://clinicaltrials.gov) (accessed on 1 June 2021) (NCT04532905). Initially, 13 young male participants were recruited and allocated into two groups between July 2020 and February 2021 through convenience sampling. Among these participants, three were excluded. Thus, five participants were included in the untrained group (with no weight training experience) and trained group (with 2 months of weight training experience). Each participant signed a written consent form before the start of the study. The inclusion criteria were: (1) healthy male individuals of 20–40 years of age; (2) no metabolic, systematic, or musculoskeletal disease or injury; (3) no recent surgical procedure that could limit exercise training; (4) taking no medications, especially sedatives, antidepressants, antihypertensive, etc.; and (5) physically fit according to the Physical Activity Readiness Questionnaire (PAR-Q) [19]. The exclusion criteria were a diagnosis of any metabolic, systematic, or musculoskeletal disease; an injury; or a recent

surgery (Figure 1). Functional outcome measurements and data analyses were performed by trained research staff who were not involved in the intervention. Participants were blinded to their groups in this study.

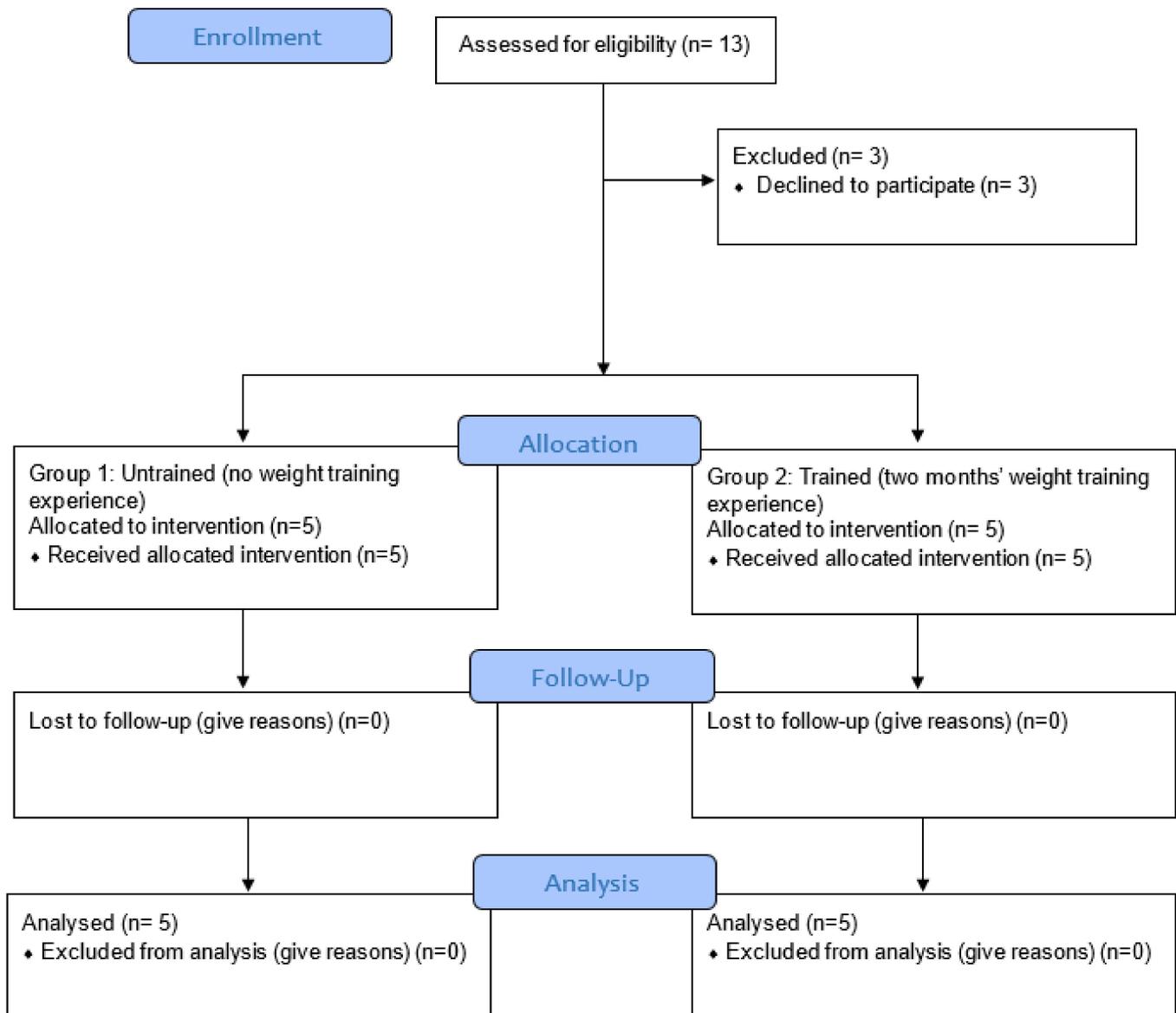


Figure 1. Study Flow Diagram.

Experimental procedure: Each participant visited the training room, where testing and data collection were completed, for five separate sessions. All participants were instructed to eat a meal 2–4 h before testing, to avoid alcohol and caffeine ingestion for 24 h before testing, and to refrain from strenuous exercise for 24–48 h before testing [20].

Session 1: During the first visit, baseline body weight (kg), height (cm), body mass index (BMI), and body fat percentage were measured using a Karada Scan-371 body scale (Omron, Kyoto, Japan). Each participant was evaluated using the PAR-Q for physical fitness, and the testing and training procedures were explained to them by an expert researcher. In this session, participants performed a familiarization exercise before the training sessions. The performed exercises were the dumbbell bent-over row, deadlift, and lunge with the participant's preferred weight, with three sets of 10 repetitions performed at a cadence of 2 s up and 2 s down using an audible metronome. An audible cadence was used to control for potential variations in the lifting cadence of the participants. Between

each set, there was a 3 min rest period, and there was a 10 min rest between each type of exercise [21].

Session 2: During this session, each participant performed a maximum of three to five sets to achieve their maximum 1 RM for the dumbbell bent-over row, deadlift, and lunge exercises. Briefly, the participants performed a warmup consisting of 8 to 10 repetitions using a light weight, 3 to 5 repetitions using a moderate weight, and 1 to 3 repetitions using a heavy weight. After the warmup sets, the 1 RM strength of the participants was tested by increasing the resistance on subsequent attempts until the participant was unable to complete an attempt using proper technique through the full range of motion [22]. Between each set, the participant was given a 2–4 min rest interval. Participants performed one repetition with each load to minimize muscle fatigue. Between the 1 RM bent-over row, deadlift, and lunge, there was a 10–15 min rest period, during which participants were allowed to walk, perform light dynamic movements, and consume small amounts of water [21]. A familiarization session was added to practice the proper technique before the start of formal training.

Sessions 3–5: Participants performed three weight training sessions on separate days, each at the same time of day, which consisted of the bent-over row, deadlift, and lunge exercises at 60% of 1 RM, with three sets of 10 repetitions performed at a cadence of 2 s up and 2 s down using an audible metronome. An audible cadence was used to control for potential variations in the lifting cadence of the participants. Between each set, there was 3 min rest period, and a 10 min rest between each type of exercise was included [21]. A minimum of a 24–48 h rest interval between resistance training sessions was included. Oxygen consumption (VO_2) was recorded during each training session through a breath-by-breath analysis using a Cortex Metalyzer 3B (Cortex, Leipzig, Germany) while the participant was wearing a mask. The flow and gas sensors were calibrated before every test. The temperature and the humidity of the room were respectively set to 22–27 °C and 52–64%. Before beginning training, participants were provided with an explanation of the Borg Rate of Perceived Exertion Scale (6–20; RPE). The VO_2 , RER, and HR were recorded for a total of 49 min for each training session, including the resting, exercise, and recovery periods. The blood pressure and RPE were recorded before the start of training and immediately after each exercise using a portable Omron sphygmomanometer and the RPE scale.

Outcome measures: The recorded variables were VO_2 (mL/kg/min), VO_2 (L/min), METs, RER, HR (bpm), SBP (mmHg), DBP (mmHg), and RPE score. For each exercise of three sessions, the MET intensity (Figure 2), RER, HR, blood pressure, and RPE are presented as average values. For MET, RER, and HR, only exercise data were included, while for blood pressure and RPE, values recorded after each exercise were included. The summed EE in kilocalories (kcal) for each exercise included the exercise and rest period after the exercise set. EE was computed from VO_2 (mL/kg/min) as VO_2 (mL/kg/min) \times body weight/1000 and multiplied by 5 kcal for exercise EE [18] and 4.7 kcal for the rest period after exercise [23].

Statistical analysis: Raw data from the cortex metalyzer were exported and processed in Excel software. For statistical analysis, SPSS software (IBM SPSS Statistics version 19, Armonk, NY, USA) was used. Study demographics are presented in the form of descriptive statistics (Table 1). Variables for the statistical analysis included RER, HR, SBP, DBP, RPE, and calculated EE average values, which are presented in Tables 2 and 3. For all three training sessions, RER, HR, SBP, DBP, and RPE were compared between the two groups using one-way ANOVA (Table 2). The significance level was set to $p < 0.050$. Energy costs through summed values of EE of each set of three exercises for both groups are presented for each training session (Table 3).

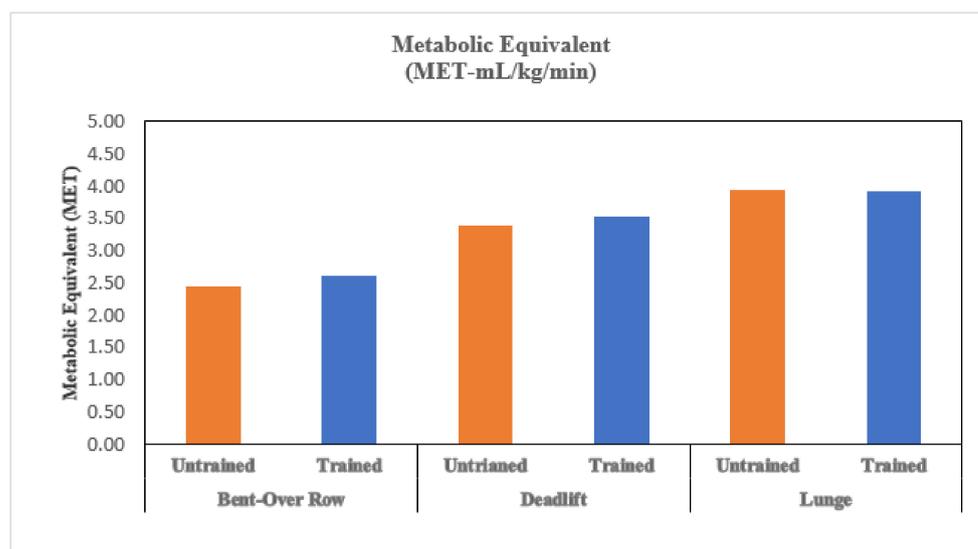


Figure 2. Metabolic Equivalent (MET) of weight training exercises. ($n = 10$).

3. Results

3.1. Baseline Characteristics of Participants

Thirteen participants were initially selected to take part in our study, and three participants were excluded. We included 10 individuals who fulfilled the inclusion criteria, and these individuals were assigned to an untrained group and a trained group ($n = 5$ for each group). Baseline characteristics of all participants, including age, body weight (BW), height, BMI, % body fat, lean body mass (kg), habitual activity/week (h), and training load for each exercise are shown in Table 1. The two groups did not differ significantly in age, BW, height, BMI, or % body fat. However, the training load at 60% 1 RM differed between the two groups and the exercise type because of training experience. None of the participants in either group experienced any adverse events during or after the three training sessions.

Table 1. Baseline Characteristics of Study Participants ($n = 10$).

Group	Untrained ($n = 5$)	Trained ($n = 5$)
Age (years)	24.80 ± 2.40	28.40 ± 4.63
Weight (kg)	78.66 ± 15.52	80.72 ± 12.32
Height (cm)	174.60 ± 2.80	173.60 ± 3.61
Body mass index (kg/m^2)	25.72 ± 4.59	26.78 ± 4.21
Lean body mass (kg)	63.16 ± 11.80	65.76 ± 7.44
% Body fat	22.54 ± 9.44	22.74 ± 4.46
Habitual activity/week (h)	3.14 ± 0.92	5.52 ± 0.96
RM 60% of Bent-Over Row (kg)	28.50 ± 8.43	43.00 ± 11.14
RM 60% of Deadlift (kg)	31.50 ± 10.00	56.00 ± 12.08
RM 60% of Lunge (kg)	19.35 ± 6.26	31.00 ± 4.85

Values are expressed as the means ± standard deviation. RM, repetition maximum. Training loads are presented for dumbbell exercises for both sides (left and right) in kilograms (kg).

3.2. Metabolic Equivalent (METs) of Training Exercises for Three Sessions

The mean MET intensities of each exercise of the three training sessions are presented in Figure 2. The METs for the dumbbell bent-over row were 2.44 ± 0.59 for the untrained group and 2.60 ± 0.39 for the trained group; these levels are considered light exercise. The 3.40 ± 0.65 and 3.53 ± 0.66 METs recorded for the dumbbell deadlift and 3.94 ± 0.77 and 3.92 ± 0.47 METs recorded for the dumbbell lunge in the untrained and trained groups, respectively, are considered moderate training expenditures.

3.3. Physiological Profiles during Three Training Sessions

The RERs for the bent-over row and deadlift exercises were high for both groups and ranged from 1.05 to 1.08. However, the HR and SBP increased during all three exercises for both groups, from 111 to 137 bpm and from 136 to 146 mmHg, respectively. DBP did not change much for each exercise. Some of the parameters significantly differed between groups, namely the HR during the lunge exercise, (137.66 ± 12.03 bpm for the untrained group and 122.58 ± 10.71 bpm for the trained group, $p = 0.001$ *), and the rate of perceived exertion for the bent-over row exercise (12.80 ± 1.08 and 10.07 ± 3.15 for the untrained and trained groups ($p = 0.005$ *), respectively) (Table 2).

3.4. Energy Costs during the Three Training Exercise Sessions

The summed EEs (kcal) for each exercise including the rest period are shown in Table 3. For the bent-over row, each training had EE values in the range of 179–187 kcal for the untrained and 213–277 kcal for the trained group. The deadlift exercise showed slightly higher EE values of 238–245 and 271–282 kcal and the lunge exercise of 253–263 and 278–291 kcal for the untrained and trained groups, respectively. The sum of energy costs of the three training types ranged from 683–688 kcal for the untrained and 779–840 kcal for the trained group. The energy cost between the untrained and trained groups for each exercise differed significantly ($p = 0.001$ *– 0.006 *).

Table 2. Physiological parameters during three weight training sessions ($n = 10$).

Exercise Type	Bent-Over Row				Deadlift				Lunge				
	Group	Untrained ($n = 5$)	Trained ($n = 5$)	Δd	p Value	Untrained ($n = 5$)	Trained ($n = 5$)	Δd	p Value	Untrained ($n = 5$)	Trained ($n = 5$)	Δd	p Value
RER		1.05 ± 0.09	1.06 ± 0.09	0.01	0.676	1.06 ± 0.10	1.08 ± 0.09	0.02	0.583	0.99 ± 0.08	0.97 ± 0.08	0.02	0.429
HR (bpm)		111.68 ± 12.91	115.42 ± 10.98	3.72	0.400	126.30 ± 15.33	123.56 ± 10.65	2.74	0.574	137.66 ± 12.03	122.58 ± 10.71	15.08	0.001 *
SBP (mmHg)		135.87 ± 8.74	137.13 ± 18.27	1.26	0.810	140.40 ± 13.82	146.07 ± 19.31	5.67	0.363	142.60 ± 16.93	136.40 ± 19.07	6.20	0.355
DBP (mmHg)		72.47 ± 7.56	70.33 ± 10.41	2.14	0.526	77.93 ± 6.18	75.40 ± 9.56	2.53	0.396	75.93 ± 5.85	70.87 ± 10.13	5.06	0.104
RPE		12.80 ± 1.08	10.07 ± 3.15	2.73	0.005*	13.93 ± 1.33	12.47 ± 3.66	1.46	0.156	12.00 ± 1.31	12.00 ± 3.07	0.00	1.000

Values are expressed as means \pm standard deviation; n , number of participants; RER, respiratory exchange ratio; HR, heart rate in beats per minute; SBP, systolic blood pressure; DBP, diastolic blood pressure; RPE, rate of perceived exertion; Δd , change in values between the untrained and trained groups. * The significance level was set to $p < 0.050$.

Table 3. Energy expenditure (EE) sum in kilocalories ($n = 10$).

	Untrained ($n = 5$)			Trained ($n = 5$)			p -Value
	Session 1	Session 2	Session 3	Session 1	Session 2	Session 3	
Bent-over row	186.26 ± 28.42	187.35 ± 31.36	179.61 ± 50.80	277.25 ± 97.59	226.98 ± 37.64	213.05 ± 38.19	0.050 *
Deadlift	238.48 ± 18.68	238.75 ± 22.50	245.61 ± 21.61	271.82 ± 41.91	276.73 ± 23.68	282.85 ± 36.22	0.001 *
Lunge	259.04 ± 20.06	253.28 ± 23.22	263.61 ± 30.43	291.17 ± 46.89	278.62 ± 33.25	283.33 ± 32.81	0.006 *
Total cost	683.78	679.38	688.83	840.25	782.33	779.23	0.004 *

Values are presented as means \pm standard deviation of the energy expenditure for the exercise and resting period. * The significance level was set to $p < 0.050$.

4. Discussion

The present study reports the EEs and physiological profiles during three weight training exercises. Based on the study findings, the dumbbell bent-over row, deadlift, and lunge exercises were categorized as light to moderate intensity (2.4–3.9 METs), with higher energy costs for the trained group because of the greater training loads and metabolic rates.

The health benefits of moderate-intensity physical activity have mainly been reported for endurance exercises [24]. The previous literature is deficient in reporting energy costs of weight training exercises, and the ranges of different sets/circuits, repetitions, and total times make it difficult to compare our results with those of previous studies. In our study, a single session (49 min) consisted of three exercises, each with three sets and 10 repetitions at 60% 1 RM, which resulted in 3.4 METs, considered moderate-intensity exercise (3–6 METs) for both men and women. A previous study that utilized a single set of eight resistance exercises (24 min) for 15 RM reported a mean intensity of 3.9 METs [16]. In the present study, all three exercises were performed in a single session by both groups, so EEs increased in order from the bent-over row (2.5 METs), deadlift (3.5 METs), and lunge (3.9 METs). The lunge exercise showed a higher EE compared with the deadlift and bent-over row because the training load was low for the bent-over row and high for the lunge. The involvement of specific muscle groups makes the lunge and deadlift more intense exercises than the bent-over row. The bent-over row involves the major latissimus dorsi muscle and the deadlift involves the erector spinae, gluteals, and hamstrings, while the lunge involves the quadriceps, hamstrings, gluteals, and erector spinae. The exercise posture could be another reason for the higher EE during the lunge exercise involving the entire body movement. Because the sequence of the exercises was performed in order from the bent-over row, deadlift, and lunge, participants expended more energy when performing the lunge exercise at the end of each training session. A higher EE during the lunge (exercise = 5.28 ± 0.86 kcal/min and recovery = 9.33 ± 1.71 kcal/min) was reported by a study that utilized a circuit of four resistance exercises (push-ups, curl-ups, lunges, and pull-ups) in young healthy men [25].

The RER did not reach statistical significance in our study, but it increased with the exercise intensity because it is an indirect measure of the relative utilization of carbohydrates and lipids to overall EE under steady-state conditions. Usually, a high RER reflects carbohydrate oxidation, and a low RER indicates lipid oxidation [26]. Therefore, the RER values in our study were slightly low for the untrained group during the bent-over row (1.05 ± 0.09) and deadlift (1.06 ± 0.10) exercises compared with the trained group (bent-over row at 1.06 ± 0.09 and deadlift at 1.08 ± 0.09). However, for the lunge exercise, the untrained group (0.99 ± 0.08) had a slightly higher RER than the trained group (0.97 ± 0.08). This indicates that during the training session, untrained group participants may have initially utilized more lipids and the trained group more carbohydrates, but the utilization reversed as the exercise proceeded to the lunge because the exercises were performed in the order of bent-over row, deadlift, and lunge.

Contrary to aerobic exercise, the AEE of weight training is a combination of aerobic and anaerobic components. The previous literature highlighted that during aerobic exercise, steady-state O_2 consumption and HR are linearly correlated, but this relationship is not linear during resistance exercises [23,27]. Hunter et al. [28] reported an increase in heart rate during traditional resistance training exercise and the recovery period of 143 ± 8.0 and 119 ± 12 , respectively. In the present study, HR values increased in both groups, but this increase was higher for the untrained group (111–137 bpm) than for the trained group (115–123 bpm) for all three exercises during weight training sessions because untrained group participants conducted the training sessions at comparatively low loads and had no experience with weight training. However, the lunge exercise significantly increased the HR in both training groups ($p = 0.001$ *). One study explained a possible mechanism for the increase in HR during circuit resistance training (CRT) at a moderate intensity (40% 1 RM loading). The authors explained that anaerobic factors during CRT resulted in higher HRs. High forces of contraction may impede blood flow because of the squeezing effect of the

muscles on the blood vessels. The reduced blood flow to the exercising muscles probably restricts the transport of the required oxygen to the mitochondria and the elimination of metabolic end-products [29]. However, as CRT progresses, metabolites (such as lactate and hydrogen ions) accumulate, causing a rise in HR above the point where oxygen is required. In addition, greater activation of neurological receptors increases tachycardia [30].

In this study, SBP increased after 60% 1 RM of each exercise in both groups, ranging from 135 to 146 mmHg. In comparison with the untrained group (135–142 mmHg), the trained group (136–146 mmHg) showed a slightly higher SBP for the bent-over row and deadlift exercises, but the lunge exercise resulted in an SBP of 142.60 ± 16.93 for the untrained group and 136.40 ± 19.07 for the trained group without reaching significance. The reason for this increase may have been the fact that when exercise is begun, the body is not well prepared for exercise loads and compensates by increasing the SBP, but after performing the two exercises, the SBP did not increase much because the body had adjusted to the training loads. On the other hand, the untrained group showed a greater DBP for all three exercises (72–77 mmHg) than the trained group (70–75 mmHg) without attaining significance. A previous study reported that blood pressure increased after a 95% of 1 RM weightlifting session for 90 min in professional bodybuilders [29]. The greater pressure was noted during a double leg press, with mean values of 320/250 and 255/190 mmHg for arm curls when repetitions were continued to failure. This increase in blood pressure may have possibly been due to (a) mechanical compression of blood vessels; (b) a potent reflex pressure response; or (c) a Valsalva response to the arm curls, overhead press, and single and double leg presses [31].

There has been little research into the EE (in kcal) during non-circuit training exercises. One study reported total energy costs during a single-set, eight-exercise protocol of 135.20 ± 16.6 kcal for men and 81.7 ± 11.1 kcal for women. However, according to ACSM guidelines, to meet the MET threshold of moderate-intensity, a volume ranging from 150–200 kcal is required for health benefits for endurance-type activities [16]. From our study, the energy costs of each exercise during a single training session are presented in Table 3. The bent-over row EE values were 176–186 and 213–277 kcal ($p = 0.050$ *) and the deadlift EE values were 238–245 and 271–282 kcal ($p = 0.001$ *), while the lunge EE values were 253–263 and 278–291 kcal ($p = 0.006$ *) for the untrained and trained groups, respectively. The EE values were higher for the trained group because of RM loading and differences in weight training experience. However, overall during each training session, both the untrained and trained groups consumed 679–840 kcal ($p = 0.004$ *). Another study measured EE in kilojoules (kJ) for bench press and back squat exercises in a single training session with 60% of 1 RM training load, and each participant performed three sets of 10 repetitions at a speed of 3 s down and 1 s up. EE values were reported using three methods, but according to the Scott method, the values ranged from 891.0 ± 165.6 to 912.3 ± 182.7 kJ [21].

The most important factor contributing to the increase in METs in the trained group might be exercise volume because participants in this group lifted higher loads than the untrained group, demanding a higher cost of energy. There may be other factors involved in this increase, such as energy intake, exercise habits, body composition, and metabolic differences, which were not evaluated in our study. Weight training is a form of interval training, in which work-to-rest ratios are prescribed according to an exercise event to replenish energy reserves of ATP. For example, an exercise of 1 s should require 10 s rest for an explosive activity (1:10 ratio) to target the phosphagen system. By contrast, in our study, the 40 s exercise set required a rest interval of about 3 min (1:4 ratio) and targeted phosphagen and fast glycolysis for ATP resynthesis [32].

Limitations

(1) The study only reported results for young healthy male participants aged 20–33 years. (2) Results are from a small sample size ($n = 10$). This protocol needs to be tested on large populations to infer health and fitness-related benefits. (3) However, the longer resting pe-

riod before the exercise was not included. In future studies, the longer resting period before the start of exercises should be included to determine the resting energy expenditure and recovery period at the end of each session. (4) This study included only aerobic/exercise components of energy expenditure. For effective measurement, the anaerobic component of weight training exercises should be evaluated in future studies. (5) The physiological parameters measured in this study were quite variable. It is imperative to determine which parameters are sensitive to weight training exercises. (6) The most important factor contributing to the increase in METs for the trained group might be exercise volume because participants in this group lifted higher loads than the untrained group, which demanded a higher cost of energy. There may be other factors involved in this increase, such as energy intake, exercise habits, body composition, and metabolic differences, which were not evaluated in our study and will be considered in future research.

5. Conclusions

Based on the study findings, it was concluded that the exercise protocol of this study utilized moderate-intensity exercise of 2.4–3.9 METs. The energy cost of each training exercise was 179–291 kcal. The physiological parameters, such as the heart rate ($p = 0.001$ *) for the lunge and the rate of perceived exertion ($p = 0.005$ *) for the bent-over row, differed significantly but did not reach significant levels for the respiratory exchange ratio or systolic and diastolic blood pressure.

Practical Implications

This kind of weight training protocol can be used for fitness and health benefits for healthy populations. By adjusting the training intensity, parameters can be utilized for obese patients, elderly patients, and patients in clinical settings.

Author Contributions: Conceptualization, M.A. and C.-W.P.; methodology, M.A., C.-H.L. and C.-W.P.; software, M.A., C.-W.W. and C.-W.P.; validation, M.A., C.-H.L., J.-H.K. and C.-W.P.; formal analysis, M.A., M.-J.H. and C.-W.P.; investigation, M.A. and M.-J.H.; resources, C.-H.L., J.-H.K., H.-C.C. and C.-W.P.; data curation, M.A., C.-W.W. and C.-W.P.; writing—original draft preparation, M.A.; writing—review and editing, M.A., C.-H.L. and C.-W.P.; visualization, J.-H.K., J.-C.L. and H.-C.C.; supervision, C.-H.L., C.-W.W., J.-H.K., J.-C.L., H.-C.C. and C.-W.P.; project administration, C.-H.L. and J.-H.K.; funding acquisition, C.-W.P. All authors have read and agreed to the published version of the manuscript.

Funding: The present study was generously funded by the Ministry of Science and Technology (110-2811-E-038-500-MY3, 109-2221-E-038-005-MY3, 109-2314-B-038-132, and 110-2314-B-038-001) and the Higher Education Sprout Project by the Ministry of Education (DP2-108-21121-01-N-08-02 and DP2-110-21121-01-N-02-01) of Taiwan.

Institutional Review Board Statement: The study was conducted according to guidelines of the *Declaration of Helsinki* and approved by the Institutional Review Board (or Ethics Committee) of the TMU Joint Institutional Review Board (IRB no: N202004023, 2 June 2020). The trial was registered at [ClinicalTrials.gov](https://www.clinicaltrials.gov) (accessed on 1 June 2021) (NCT04532905).

Informed Consent Statement: Written informed consent was obtained from all participants involved in the study.

Data Availability Statement: The data presented in this study are all available in the article.

Acknowledgments: We would like to acknowledge our very dedicated research assistants and clinic staff at Taipei Medical University Hospital and Shuang Ho Hospital for their untiring efforts in collecting data and recruiting participants in Taiwan.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

ACSM	American College of Sports Medicine
AEE	activity energy expenditure
BMI	body mass index
BMR	basal metabolic rate
BPM	beats per minute
CDC	Centers for Disease Control
CRT	circuit resistance training
DBP	diastolic blood pressure
EE	energy expenditure
HR	heart rate
IC	indirect calorimetry
IRB	institutional review board
kcal	kilocalories
kJ	kilojoules
MET	metabolic equivalent
mL/kg/min	milliliter per kilogram per minute
mmHg	millimeters mercury
PAR-Q	Physical Activity Readiness Questionnaire
RER	respiratory exchange ratio
RM	repetition maximum
RPE	rate of perceived exertion scale
RT	resistance training
SBP	systolic blood pressure
SD	standard deviation
SPSS	Statistical Package for the Social Sciences
TEE	total energy expenditure
VO ₂	oxygen consumption

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