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Metabolic Equivalents of Body Weight Resistance Training with Slow Movement: Implications for Exercise Prescription and Health Promotion

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ABSTRACT

Nakagata T, Naito H, Yamada Y. Metabolic Equivalents of Body Weight Resistance Training with Slow Movement: Implications for Exercise Prescription and Health Promotion. **JEPonline** 2018;21(5): 29-38. The purpose of this study was to evaluate metabolic equivalents (METs) and energy expenditure (EE) of BWRT-slow movement for exercise prescription and health promotion. Fifteen young men 20 to 26 yrs of age performed 6 (Squat, Lunge, Push-Up, Crunch, Hip-Lift, and Heel-Raise) BWRT-slow movement exercises with both the concentric and eccentric phases set to 3 sec. A total of 3 sets (10 reps, total 3 min) with a 30-sec rest between sets were performed for each exercise (total 4 min). Expired gas was measured using indirect calorimetry. The METs and EE were calculated using the area under the curve (AUC) during exercise and post-exercise. Oxygen consumption was elevated during a 30-sec interval between exercises and recovery phase compared with the actual exercise duration. On average, the Squat, Push-Up, and Lunge were categorized as moderate intensity (3.4 to 3.7 METs) while the Crunch, Hip-Lift, and Heel-Raise were categorized as light intensity (1.8 to 2.3 METs). METs intensity of the BWRT-slow movement exercises was categorized as light-to-moderate intensity (1.8 to 3.7 METs). The results are important in prescribing RT programs using the BWRT-slow movement.

Key Words: Home-Based Exercise, Light-Intensity, Muscle-Strengthening Activity, Oxygen Consumption

INTRODUCTION

The health benefits of enhancing muscle fitness are well established. In particular, recent findings indicate that the regular resistance training (RT) can decrease body fat, decrease blood pressure, improve cholesterol and glycemic control (5,9), and overall decrease the risk of heart disease. Physical activity guidelines recommend that RT programs should be performed a minimum of two non-consecutive days each week, and the exercise mode and/or intensity should depend on the individual's physical fitness level and goals (2,21). Low fitness individuals and/or beginners should begin with using their body weight (BWRT) or a low-load weight rather than using a high-load advanced training machine and/or free-weight (~60 to 80% of 1 rep maximum). The push-up exercise, for example, is a very popular BWRT exercise that results in similar muscle hypertrophy and increases in strength as does a 40% 1 rep maximal (RM) bench-press exercise after an 8-wk training program (6).

The metabolic equivalent (MET) is a unit of physiological demand for exercises based on oxygen uptake (VO_2) (3,4,10). Resistance training is considered as 3.5 METs (code 02054) and/or 5.0 METs (code 02052) in the Compendium of Physical Activities (1) with an energy expenditure (EE) in the ranged of 5 to 10 $kcal \cdot min^{-1}$ (i.e., 135 to 270 kcal for men with average height and weight). While the previous studies (3,4,10) investigated RT using training machine and/or free-weight with high-loads, there is relatively little information about the energy demands of BWRT. To our understanding, Vezina et al. (19) may have been the first to examine the metabolic aspects of BWRT (Push-Up, Lunge, Curl-Up, and Pull-Up). They calculated the EE with a post-exercise EE component, given that the EE peaks in post-exercise after a single set of RT (13,14).

The main limitation of BWRT is that the exercise is limited to low- to middle-load so that the effect of BWRT on skeletal muscle is weaker when compared to the typical RT program with a high-load. Previous studies (18,20) examined "BWRT with slow movement (BWRT-slow)" in older adults to overcome the limitation, and found that this exercise improved muscle fitness by increasing strength, function, and hypertrophy. Also, the effects of whole-body low-intensity RT with slow movement and tonic force generation on muscular size and strength in young men has been reported on as well (16,17).

We hypothesised that the metabolic demands and exercise intensities of BWRT-slow is not high, and thus BWRT-slow can be conducted as a part of a person's daily exercise (although the metabolic aspect of BWRT-slow has not been examined well). This information should help encourage the use of BWRT-slow exercise by health professionals. Thus, the purpose of this study was to investigate METs and time-course of the EE of BWRT-slow.

METHODS

Subjects

This study included fifteen young male adults (age, 21.7 ± 1.7 yrs; height, 171.9 ± 6.0 cm; weight, 64.8 ± 7.5 kg, Table 1). Prior to the study, all subjects provided written consent to participate after receiving information on the procedures and purpose of the study. The study protocol was approved by the Research Ethics Review Board of the Juntendo University (28-3), and it was conducted in accordance with the Declaration of Helsinki for Human Research.

Experimental Design

The duration of the experiment was 90 min (resting in a chair for 30 min to measure the resting metabolic rate (RMR), 3 min of each exercise with a 5-min recovery between each exercise). The subjects in this study refrained from any strenuous physical activity from the day before the experiment day; fasting (no water restriction) was begun 4 hrs before the start of the experiment. After measurement of RMR, the subjects carried out the BWRT-slow. All measurements were carried out in a laboratory where temperature and humidity of the internal atmosphere were adjusted to 20°C and 50%, respectively, between August of 2016 and March of 2017.

Anthropometry and Body Composition

The height of the subjects was measured to the closest 0.1 cm using an analog height meter. Body fat percentage and skeletal muscle mass were estimated using the impedance method (Inbody 730, Biospace, Tokyo, Japan) while wearing underwear and barefoot.

Table 1. Subject Characteristics (N = 15).

Variables	Mean ± SD	Range
Age (yrs)	21.7 ± 1.7	20 – 26
Height (cm)	171.9 ± 6.0	162.3 ± 180.0
Weight (kg)	64.8 ± 7.5	57.1 – 78.0
BMI ($kg \cdot m^{-2}$)	21.9 ± 1.8	18.8 – 25.2
Muscle Mass (kg)	33.0 ± 3.7	28.7 – 41.0
Fat Mass (kg)	6.9 ± 2.6	1.7 – 12.6
Body Fat Ratio (%)	10.5 ± 3.4	3.0 – 16.7
RMR ($mL \cdot kg^{-1} \cdot min^{-1}$)	3.7 ± 0.4	3.1 – 4.4
Resting HR ($beats \cdot min^{-1}$)	57 ± 10	36 – 72

BMI = Body Mass Index; **RMR** = Resting Metabolic Rate; **HR** = Heart Rate. Ranges refers to minimum - maximum

Resistance Training Protocol

We selected the following 6 exercises: (a) Squat; (b) Lunge; (c) Push-Up; (d) Crunch; (e) Hip-Lift; and (f) Heel-Raise. Details of the exercise are shown in Table 2. The subjects performed BWRT-slow with a 3-sec concentric and a 3-sec eccentric duration, and adjusted the rhythm with the sound of a metronome. A total of 10 reps were considered 1 set (1 min in total) with a 30-sec interval between the sets, and a total of 3 sets were performed for each exercise. It took 4 min to complete one exercise (exercise 1 min x 3 and interval 30 sec x 2). In order to eliminate the influence of the execution order, the order of the six BWRT-slow was randomized between subjects. Subjects completed the experiment in 1 day.

Table 2. Details of the Body Weight Resistance Training with Slow Movement (BWRT-Slow).

Exercise	Instructions
Squat	In a shoulder-width stance, bend the knees and lower hips like sitting in a chair until the thighs become parallel to the floor. Do not move the knees forward beyond the toes during exercise.
Lunge	Stand with the dominant foot in front, bend the knees and lower hips and until the front thighs become parallel to the floor.
Push-Up	Place the hands on the floor at about 1.5 shoulder-widths, and bend the elbows until the chest almost touches the floor. Start with plank position, push through the heels of your hands in order to return to the starting position.
Crunch	Lie down on the floor with back flat, knees bent, and feet resting on the floor. Raise head and shoulders only a few inches from the floor. Keep with lower back stays on the floor.
Hip-Lift	Lie on the floor with back flat, knees bent, and place hands out to body sides palms flat. Raise hip off the floor by extending hips upward until hips and thighs are in a straight line, and return to start position. Keep back straight.
Heel-Raise	Stand with feet a few inches apart, raise heels off the floor while keeping your knees straight, lower heels to the floor. Do not touch heels on the floor. An examiner stands in front of subjects, they put hands on examiner's shoulder.

Indirect Calorimetry Measurement

Respiratory gas measurement using indirect calorimetry was carried out in our laboratory as previously described (8). Respiratory gas during rest and exercise was measured using a face mask and expiratory gas analyzer (AE-300s, Minato Medical Science Company, Ltd.). Prior to the start of the experiment, the flow rate sensor was calibrated using a 2 L syringe, and the concentration sensor was calibrated for gas of known concentration (O_2 14.98%, CO_2 4.99%, N_2 balance; O_2 20.73%, N_2 balance) and air. All data were processed every 30 sec and the ventilation volume (V_E), VO_2, and carbon dioxide production (VCO_2) were measured. The EE was calculated to include the post-exercise in accordance with previous study (during exercise; O_2 1 L = 5 kcal, during interval between exercises and recovery phase; O_2 1 L = 4.7 kcal) (19). During the 30-min rest period, the average value during the last 10 min was defined as the individual's resting metabolic rate (RMR). The VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$) of RMR was designated as 1 MET. METs intensity was defined as that area under the curve (AUC) that included both exercise (the first set was not included) and interval durations was divided by individual RMR.

Statistical Analyses

Microsoft Office Excel 2017 and PASW Statistics 17.0 (Current name; SPSS, IBM Inc.) were used for data processing and statistical analyses, respectively. All variable results are presented as mean ± standard deviation (SD). A one-way ANOVA and a multiple comparison test Bonferroni *post hoc* multiple comparison tests were conducted for the test of significant differences among the 6 types of exercises. Statistical significance level was set at an alpha level of $P<0.05$.

RESULTS

All subjects successfully performed the experiment. Figure 1 shows the mean VO_2 during RT and the recovery phase. The first set of VO_2 was significantly lower than second and third set (except for Heel-Raise), and the first set was not included in the final calculation of METs and EE in accordance with a previous study (19). From a metabolic point of view, the VO_2 was elevated during the interval between the exercises and the recovery phase, values at recovery phase at 2 min were still significantly higher than the resting level in all exercises.

Table 3 shows the mean METs, EE, HR, and RPE of BWRT-slow. With regard to METs, Squat, Push-Up, and Lunge were moderate intensity (3.4 to 3.7 METs) on average while the others were low intensity activities (1.8 to 2.3 METs). The calculated EE for Squat, Push-Up and Lunge were about 6.4 to 6.7 kcal·min^{-1} on average, The Crunch, Hip-Lift and Heel-Raise were below 3.4 to 4.2 kcal·min^{-1}.

Table 3. METs Intensity, HR, RPE, and Energy Expenditure during Resistance Training.

Exercise	METs Intensity	HR (beats·min^{-1})	RPE	EE (kcal·min^{-1})
Squat	3.7 ± 0.5 ‡¶§	94 ± 11 ‡¶§	13 ± 1 †#§	6.7 ± 1.3 ‡¶§
Lunge	3.4 ± 0.6 ‡¶§	97 ± 16 ‡¶§	15 ± 2 *§¶	6.4 ± 2.2 ‡¶§
Push-Up	3.5 ± 0.4 ‡¶§	90 ± 12 §¶	14 ± 1 *§¶	6.5 ± 1.5 ‡¶§
Crunch	2.3 ± 0.4 *†#§	81 ± 14 *†§	14 ± 2 §¶	4.2 ± 1.1 *†#§
Hip-Lift	2.1 ± 0.4 *†#§	76 ± 10 *†#	11 ± 2 †#‡	3.9 ± 1.1 *†#§
Heel-Raise	1.8 ± 0.2 *†#¶	74 ± 12 *†#‡	10 ± 2 *†#‡	3.4 ± 0.9 *†#‡¶

METs = Metabolic Equivalents; **HR** = Heart Rate; **RPE** =R of Perceived Exertion; **EE** = Energy Expenditure.
Significantly different *vs. Squat, †vs. Push-Up, #vs. Lunge ‡vs. Crunch, ¶vs. Hip-Lift, §vs. Heel-Raise

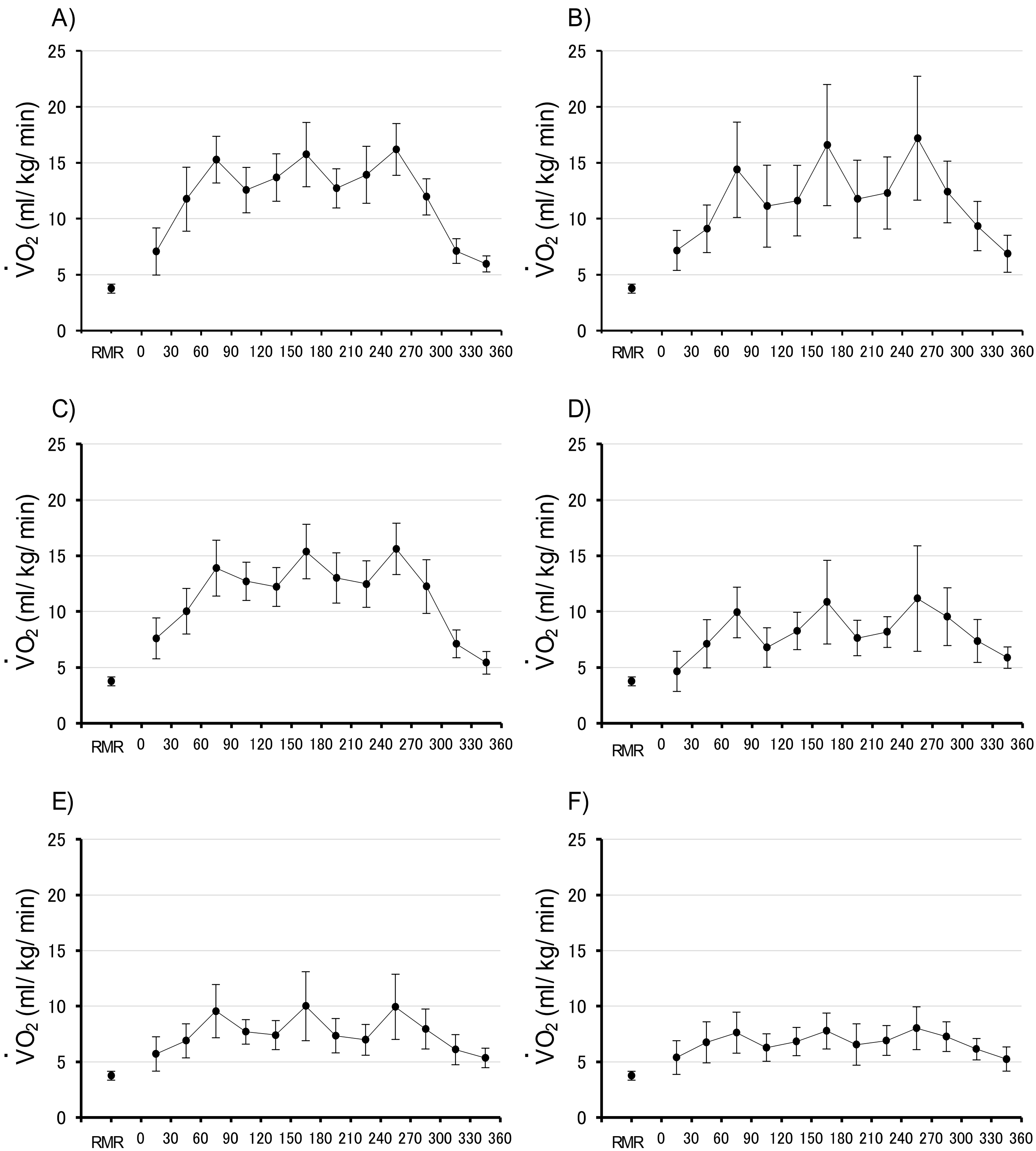

Figure 1. Time course of oxygen consumption ($\dot{V}O_2$) of resting metabolic rate (RMR) and during BWRT-slow and recovery phase until 2 min. Gray color is exercise period. A) Squat, B) Push-up, C) Lunge, D) Crunch, E) Hip-lift, F) Heel-raise.

DISCUSSION

Resistance training (RT) is an intermittent exercise that includes bouts of exercise and short intervals to recover. Knuttgen (7) reported that the energetic profile of RT is different from mild aerobic exercise (such as walking, jogging, or cycling under a given speed). In general, the VO_2 of different aerobic exercises increase gradually to achieve steady-state during the submaximal effort, and then decreases exponentially toward resting levels when the exercise is stopped. On the other hand, the subject's VO_2 does not achieve steady-state during RT. In fact, the VO_2 increases immediately after exercise during the interval phase, regardless of whether fatigue is involved or not (13,14). As shown in Figure 1, although the intensity of BWRT-slow is much lower than the common RT exercise using a training machine or free-weights with a high-load, first set was lower than the second and third sets except for the Heel-Raise. The VO_2 of all BWRT-slow movements increased during the interval or recovery phase compared with the actual exercise phase.

Also, the VO_2 at 2 min of post-exercise was still significantly higher when compared to the individual's RMR ($P<0.001$). Hence, BWRT-slow is an activity that recruits both aerobic and anaerobic energy systems. The possible mechanisms for the increase in VO_2 during post-exercise have been discussed (11,12). They focus on working muscle, blood flow to working muscle that was restricted, and impeding O_2 delivery during RT (15). Tanimoto et al. (16) showed that low intensity knee extension exercise with slow movement cause lowered muscle oxygenation level during exercise and post-exercise as compared to low intensity with normal speed using electromyographic and near-infrared spectroscopic analyses. Our study did not measure blood flow of the working muscle or oxygenation level though, performing BWRT with slow movement may have caused a similar muscle environment and, therefore, an overshoot of VO_2 may have taken place during the interval and recovery phase.

The METs value of physical activities and different exercises are defined as the ratio of the work metabolic rate to 1 MET, and routinely used to prescribe exercise intensity in exercise programs. The CDC/ACSM and the Compendium of Physical Activities defined light intensity between 1.6 to 2.9 METs, moderate intensity between 3.0 to 5.9 METs, and vigorous intensity greater than 6.0 METs. The normal model to calculate METs of a given exercise uses VO_2 when the steady-state is achieved. However, because the VO_2 of RT does not achieve steady-state and often increases during the post-exercise period, we calculated METs intensity values using the area under the curve (AUC) divided by the individual's resting metabolic rate (RMR). The present study indicates that 3 of the 6 types of exercises (Squat, Push-Up, and Lunge) ranged 3.4 to 3.7 METs, which were categorized as moderate intensity similar to walking at a usual speed of 4.0 $km \cdot hr^{-1}$. On the other hand, the Crunch, Hip-Lift, and Heel-Raise were classified as light intensity of 1.8 to 2.4 METs. The Squat, Push-Up, and Lunge exercises are multi-joint movements. They stimulate larger and more multiple muscles. Hence, the differences METs were not surprising. Further analysis clarified that the METs of BWRT-slow was determined by body weight and muscle mass, there were no relationships between METs and weight or muscle mass.

From a practical perspective, the BWRT-slow training program is a feasible alternative for performing traditional RT using a training machine or free-weights with high-load. The findings in the present study indicate that the BWRT-slow which is light-to-moderate intensity physical activity (1.8 to 3.7 METs) with an exercise heart rate in all the exercises less than

100 beats·min^{-1} (50% age-predicted HR max). Therefore, BWRT-slow is considered to be a useful and safe approach to exercise training for low-fitness individual and/or beginners.

We also estimated the EE including post-exercise when divided by the actual exercise 2 min, Squat, Push-Up, and Lunge ranged 6.4 to 6.7 kcal·min^{-1} on average; whereas, the Crunch and Hip-Lift ranged 3.9 to 4.2 kcal·min^{-1} with the Heel-Raise the lowest value (3.4 kcal·min^{-1}) (Table 3). Gross EE depends on height, weight, and muscle mass though, if average men performed 6 BWRT-slow with 3 sets, the gross EE is estimated to be 100 kcal. BWRT-slow is effective for improvement of muscle fitness variables (e.g., strength, function, and hypertrophy), although there should not be excessive EE or weight control (reduction) as compared to RT using a training machine or free-weights.

CONCLUSIONS

We conclude that low-load BWRT with slow movement recruits both aerobic and anaerobic energy systems with a MET intensity that ranged from light-to-moderate intensity physical activity (1.8 to 3.7 METs). The results of this study are valuable for the exercise and/or health professional to prescribe RT programs using BWRT-slow for all population groups, especially the low fitness individual or beginner. While all subjects in the present study were healthy young men, it is important that additional research is carried out to investigate the influence of different ages and women.

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