



Original Research

Run Economy on a Normal and Lower Body Positive Pressure Treadmill

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ABSTRACT

International Journal of Exercise Science 10(5): 774-781, 2017. Lower body positive pressure (LBPP) treadmill running is used more frequently in clinical and athletic settings. Accurate caloric expenditure is required for proper exercise prescription, especially for obese patients performing LBPP exercise. It is unclear if running on LBPP changes running economy (RE) in proportion to the changes in body weight. The purpose of the study was to measure the oxygen consumption (VO_2) and running economy (RE) of treadmill running at normal body weight and on LBPP. Twenty-three active, non-obese participants (25.8 ± 7.2 years; $\text{BMI} = 25.52 \pm 3.29 \text{ kg}\cdot\text{m}^{-2}$) completed two bouts of running exercise in a counterbalanced manner: (a) on a normal treadmill (NT) and (b) on a LBPP treadmill at 60% (40% of body weight supported) for 4 min at 2.24 (5 mph), 2.68 (6 mph), and 3.13 $\text{m}\cdot\text{s}^{-1}$ (7 mph). Repeated measures ANOVA showed a statistically significant interaction in RE among trials, $F(2, 44) = 6.510$, $p < .0005$, partial $\eta^2 = 0.228$. An examination of pairwise comparisons indicated that RE was significantly greater for LBPP across the three speeds ($p < 0.005$). As expected, LBPP treadmill running resulted in significantly lower oxygen consumption at all three running speeds. We conclude that RE ($\text{ml O}_2\cdot\text{kg}^{-1}\cdot\text{km}^{-1}$) of LBPP running is significantly poorer than normal treadmill running, and the ~30% change in absolute energy cost is not as great as predicted by the change in body weight (40%).

KEY WORDS: Run economy, Alter G™ treadmill, LBPP, calories, VO_2

INTRODUCTION

Cardiorespiratory fitness is essential to living a healthy lifestyle and preventing disease such as type 2 diabetes, hypertension, and obesity. Exercise intensity is a key component of the benefits of fitness (15) however, the greater body weight associated with sedentary lifestyle and obesity makes it difficult to be physically active and reverse excess weight gain (10). In addition to health concerns, substantial body weight has been associated with increased likelihood of lower extremity injuries (1). Running at a reduced body weight decreases ground reaction forces and reduces the impact on the runner's joints, tendons and ligaments

(13,17). For example, research suggests that the use of a lower body positive pressure (LBPP) treadmill allows for training at high running speeds and an increased aerobic stimuli with the benefits of low vertical ground reaction forces and near normal movement pattern (14). Exercising at a lower body weight could be beneficial for an overweight or obese individual by reducing potential lower body injuries, while still allowing the individual to use calories with the goal of losing weight and reaching their goals of a healthy lifestyle (8). Oxygen consumption, heart rate, and rating of perceived exertion (RPE) are reduced during supported weight exercise with a relatively greater decline at higher treadmill speeds, therefore at higher speeds exercise is relatively "easier" (7). High caloric expenditure exercise, like running, promotes greater weight loss and more favorable cardiac health profiles (2).

Emphasis on a greater caloric expenditure relative to caloric intake is important for the overweight or obese patient. Caloric expenditure of an activity is important both for the practitioner and client. Indeed, American College of Sports Medicine (ACSM) has developed equations to estimate the oxygen cost and caloric expenditure of physical activity (18). It is unclear if these estimations for caloric energy expenditure would be valid on a LBPP treadmill.

Running economy (RE) and caloric unit cost (CUC) are measures of the efficiency of running. Run economy is defined as the steady-state oxygen consumption (VO_2) at a given running velocity and CUC is the caloric cost of the exercise at a given velocity (5,6). RE is expressed as the amount of oxygen used by the body over the total distance travelled. RE is an important determinant of success in distance running (11). Distance runners aim to have lower RE, corresponding to lower energy expenditure at a given running pace (better efficiency). Obese populations conversely, would desire high (poor) RE in order to burn more energy (kcal). To date, no studies have been conducted examining the effects of LBPP treadmill running at a reduced body weight on RE.

The measurement of RE and caloric expenditure is significant to an obese or overweight population, especially when trying to lose weight. Taking the increased stress on their joints into consideration, running on a LBPP treadmill may be ideal in facilitating weight loss in these populations. The aim of this study was to determine run economy and caloric unit cost at normal body weight (100%) and at a 40% reduced body weight using an Alter G™ (LBPP) treadmill during three different running speeds. It was hypothesized that the change in metabolic cost and caloric expenditure with reduced weight would be proportional to the change (40% less) in body weight.

METHODS

Participants

Twenty-three active, non-obese volunteer participants (Age: 25.8 ± 7.2 years; BMI: 25.52 ± 3.29 $\text{kg}\cdot\text{m}^{-2}$) were recruited for this study through word of mouth on the University campus (Table 1) and local community. All participants completed a health risk appraisal (ACSM risk factor analysis) and PAR-Q form. In addition, the protocol below was approved by the University's IRB and all participants completed an informed consent. Inclusion criteria for volunteers

included apparently healthy adults, age 18 to 50 years old. Volunteers were excluded from the study if they were moderate or high risk as determined by ACSM risk factor analysis or not able to run for four minutes at 7 mph (8:30 mile per minute pace).

Table 1. Subject Characteristics

	Number	Age (yrs)	Weight (kg)	LBPP Weight (kg)	BMI
Female	10	30.3 ± 17.2	61.8 ± 8.4	37.1 ± 5.0	25.34 ± 4.94
Male	13	22.3 ± 2.6	82.3 ± 9.0	49.4 ± 5.4	25.66 ± 2.87
Total	23	25.8 ± 7.2	73.4 ± 13.4	44.0 ± 8.1	25.52 ± 3.29

Protocol

Participants completed two bouts of running exercise in a counterbalanced manner: (a) running on a normal treadmill (NT) and (b) running on a LBPP treadmill (Alter G™ #F320) at 60% of normal body weight (40% of body weight supported) for 4 min at 2.24, 2.68, 3.13 m·s⁻¹. Subjects rested for four minutes before starting the protocol, then walked at 0.89 m·s⁻¹ for two minutes, and then ran for four minutes at each speed with a two minute walking recovery between each stage. Oxygen consumption was measured using open flow indirect calorimetry (Ultima series, MGC Diagnostics and Breeze 8.30 software) and last minute averages were defined as steady state. The metabolic system was calibrated with known oxygen and carbon dioxide concentrations and flow was calibrated with a 3.0 L syringe.

Statistical Analysis

Recording of steady state VO₂, treadmill speed, and RER as well as the participant's weight (both supported and normal) were used to analyze run economy per participant. A two-way repeated measures ANOVA (speed × treadmill weight) was run to determine the effect of treadmill weighted condition and treadmill speed on absolute VO₂ and RE. If significant differences were found then simple main effects for were run with post-hoc analyses using Bonferroni test. The dependent variables studied were VO₂ and RE and independent variables were treadmill weighted condition (100 vs. 60% of body weight) and treadmill speed (2.24, 2.68, 3.13 m·s⁻¹). Statistical analysis was completed using IBM SPSS statistics version 23 software with a *p* value set at 0.05. Partial eta squared (partial η²) was calculated and reported in the Results section to estimate effect size.

RESULTS

Volunteers' average (± SD) absolute VO₂ for three treadmill speeds (TM) was 2281.5 ± 376.6, 2609.5 ± 427.4, and 2730.2 ± 541.7 ml O₂·min⁻¹, respectively. Average LBPP absolute VO₂ for three treadmill speeds was 1714.1 ± 374.6, 1913.2 ± 478.8, and 2064.4 ± 470.2 ml O₂·min⁻¹, respectively (see Figure 1). As expected, the absolute VO₂ was greater as treadmill speed increased for both conditions. The lower intensity of the LBPP treadmill resulted in a lower VO₂ at all treadmill speeds compared to NT. Similar results are shown with relative VO₂ (see Figure 2).

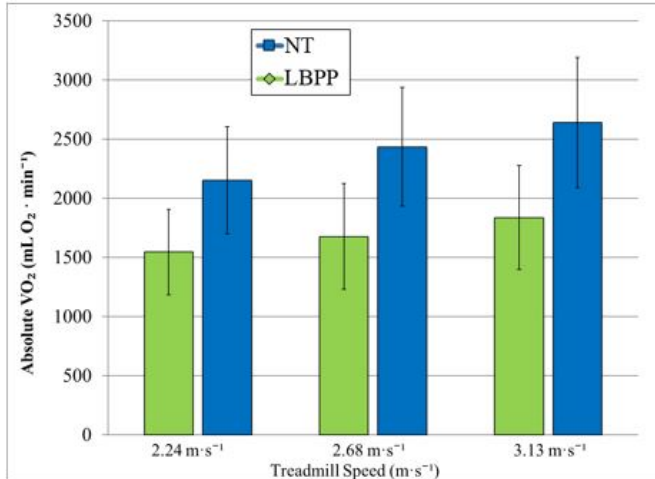


Figure 1. Absolute oxygen consumption measured at three different treadmill speeds on normal treadmill (NT) and a lower body positive pressure (LBPP) treadmill. Values are mean ± SD. Blue represents NT, green represents LBPP.

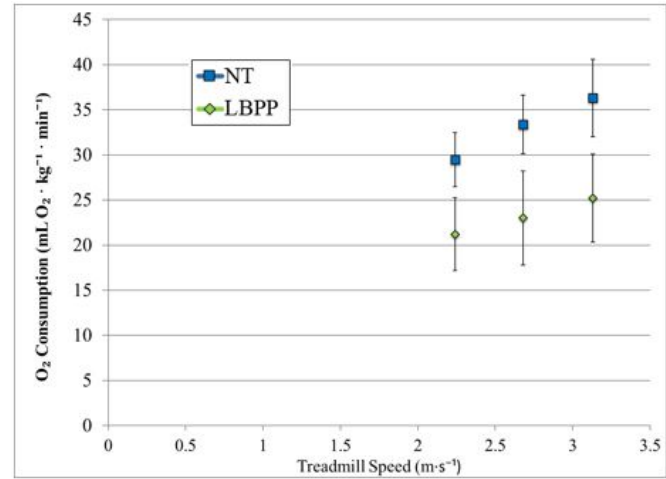


Figure 2. Relative oxygen consumption (per normal e.g., 100% body weight) measured at three different treadmill speeds on normal treadmill (NT) and a lower body positive pressure (LBPP) treadmill. Values are mean ± SD. Blue represents NT, green represents LBPP.

Running economy was calculated as oxygen consumption per kg body weight per km of distance traveled. The RE for three increasing speeds on LBPP treadmill was 263.8 ± 50.0 , 238.4 ± 53.8 , and 223.8 ± 43.2 ml O₂·kg⁻¹·km⁻¹, respectively. Running economy for three increasing NT treadmill speeds was 219.9 , 207.6 ± 20.2 , and 193.4 ± 22.9 ml O₂·kg⁻¹·km⁻¹, respectively (see Figure 3). Two-way repeated measures ANOVA was run to determine the effect of treadmill weighted condition and treadmill speed on RE.

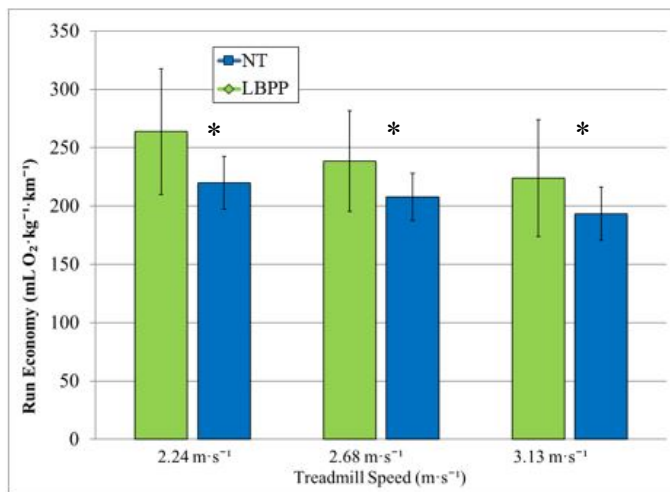


Figure 3. Run economy (per LBPP weight e.g., 60% body weight) measured at three different treadmill speeds on normal treadmill (NT) and a lower body positive pressure (LBPP) treadmill. Values are mean ± SD. Blue represents NT, green represents LBPP. Repeated measures ANOVA showed a statistically significant interaction in RE among trials, $F(2, 44) = 6.510$, $p < .0005$, partial $\eta^2 = 0.228$. RE significantly greater for LBPP across all three speeds (*) and RE significantly decreased as speeds increased for both treadmills ($p < 0.005$).

A significant two-way interaction was reported with RE among trials, $F(2, 44) = 6.510$, $p < .0005$, partial $\eta^2 = 0.228$. Simple pairwise comparisons showed significant differences in RE at all speeds between LBPP and NT. In addition, RE was significantly lower as speed increased ($p < 0.005$) for both LBPP and NT.

DISCUSSION

Running economy relative to the changes in body weight on a LBPP treadmill was the topic of our study. The importance from a theoretical perspective was to show a proportional change between the body weight and run economy on exercising on a LBPP treadmill. From a practical perspective, the importance of this study was to find whether weighing less negatively or positively affects run economy and caloric expenditure, thus affecting the runner's exercise. We predicted that the change in run economy would be proportional to the change in body weight (e.g. 40%). We would predict that the relative VO_2 (relative to 60% of body weight e.g., LBPP weight) should be similar for both treadmills at the same speed. Yet, our measured relative VO_2 was greater for the LBPP treadmill (see Figure 4) that resulted in a poorer RE (Figure 2). In this study, it was found that the difference in absolute VO_2 with unweighting was not as great as expected (~30% compared to expected 40%). This higher than expected metabolic cost resulted in a poorer (higher) RE on the LBPP (see Table 2).

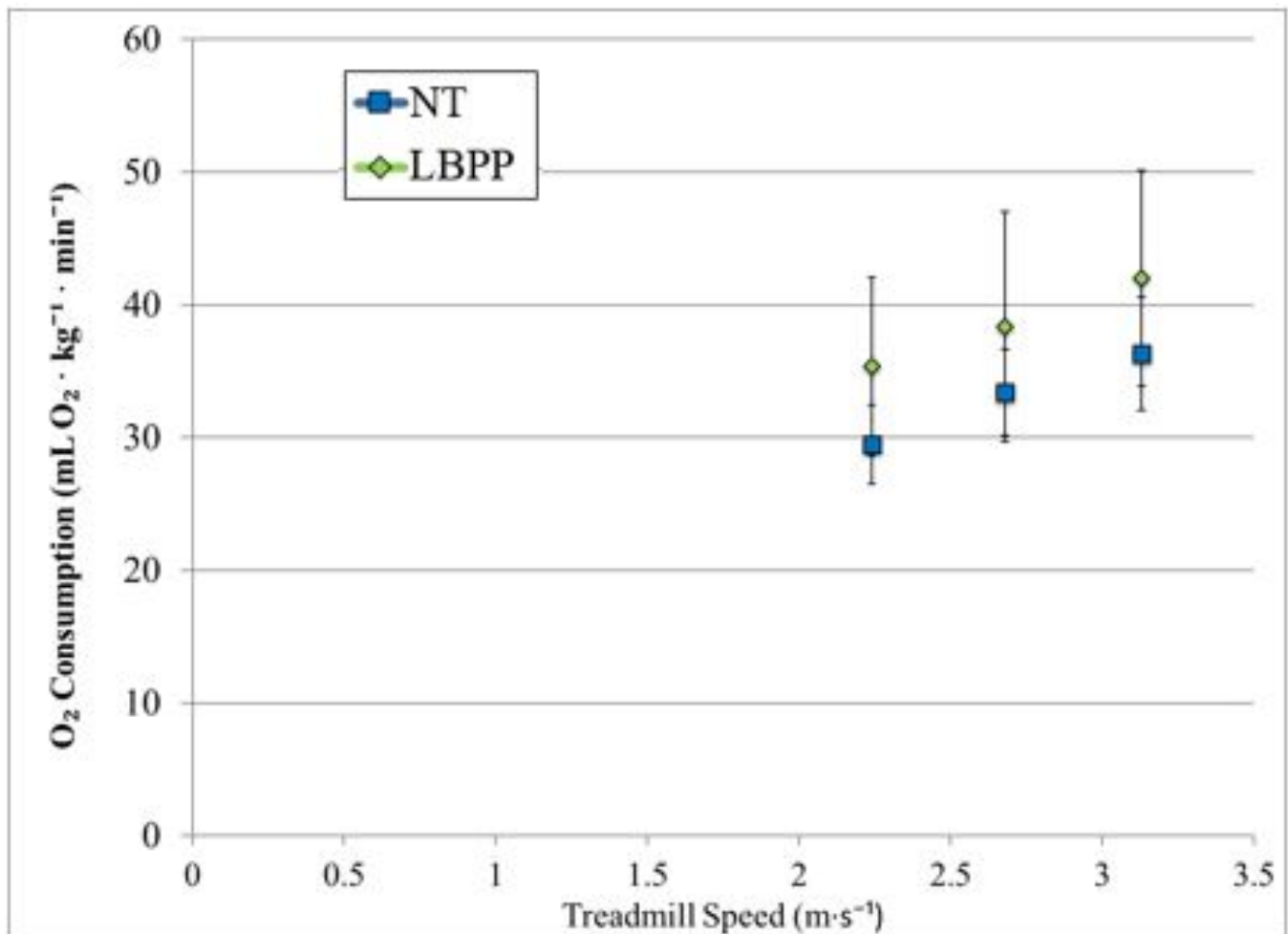


Figure 4. Relative oxygen consumption (per LBPP e.g., 60% body weight and 100% body weight) measured at three different treadmill speeds on normal treadmill (NT) and a lower body positive pressure (LBPP) treadmill. Values are mean \pm SD. Blue represents NT, green represents LBPP.

Table 2. Percent change from 100 to 60% body weight for run economy and caloric unit cost at three different treadmill speeds. Percent change of absolute VO_2 from 100% (normal treadmill) to 60% (LBPP treadmill) was less than the expected difference due to change in weight (~30% vs. expected 40%).

	Speed (m s^{-1})	LBPP Treadmill	Normal Treadmill	% Change
Absolute VO_2 ($\text{mL O}_2 \text{ min}^{-1}$)	2.24	1546.5 \pm 361.2	2152.0 \pm 452.9	28.14
	2.68	1677.5 \pm 447.7	2435.5 \pm 501.5	31.12
	3.13	1838.5 \pm 437.7	2643.1 \pm 550.9	30.44
Run Economy ($\text{mL O}_2 \text{ kg}^{-1} \cdot \text{km}^{-1}$)	2.24	263.7 \pm 50.0	219.9 \pm 22.5	19.95
	2.68	238.4 \pm 53.8	208.6 \pm 20.2	14.85
	3.13	223.8 \pm 43.2	193.4 \pm 22.9	15.70

To our knowledge, no studies have been done to examine the effects of LBPP treadmill running at a reduced body weight on RE. One study on the oxygen consumption of elite distance runners on an LBPP treadmill found that the runner's oxygen uptake decreased with support, but did not in direct proportion of that support (9). This is in agreement with our study, the expected proportions between variables was lower than the percentage of supported weight. Ruckstuhl et al., (7) did calculate the percent change in VO_2 on a LBPP treadmill with unweighting. They recorded ~28% decrease in relative VO_2 at a 33% lower weight and about a 54% lower VO_2 with a 66% lower weight on a LBPP.

These values are probably calculated as relative VO_2 measurements per normal body weight (100% kg), yet the percent difference in VO_2 is slightly less than the percent decrease in supported body weight similar to our results.

Several factors have been purported to affect RE. Physiological factors such as muscle fiber types have been suggested to affect RE (11) and biomechanical factors such as ground contact time (4) and vertical displacement (16) may affect RE. Running biomechanics is altered on a LBPP treadmill and this may account for the poorer RE (12). Our prediction was a proportional change in metabolic cost with lower body weight. The LBPP treadmill decreases overall body weight (in our study by 40%), yet this is achieved by only the lower half of the body lifted off the treadmill. The upper body could possibly be doing the same amount of external work as on the NT as measured by Arellano and Kram (3). Our theoretical knowledge of how the factors underlying affective responses to exercise are advanced by our findings of non-direct correlation between supported weights and RE. This is relevant for an overweight or obese population as they can achieve the potential benefits of exercising at a reduced weight yet still use more calories than expected.

One limitation of the current study was that we did not use an obese population as volunteers; our conclusions of the current study are limited to the apparently healthy population studied. Limitations of the study include a relatively small sample size, $n = 23$ active, non-obese volunteers and a small effect size. Future research should be done using obese population to determine differences in their RE and caloric unit cost and how they correspond to the supported weight from a LBPP treadmill.

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