The Effect of Adding External Weight on the Aerobic Requirement of Bench Stepping

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Bench aerobics is a popular form of group exercise which incorporates stepping up and down on benches of varying heights, using a variety of stepping patterns and upper body movements similar to an aerobics class. While there is limited research available, it appears that bench aerobics is a valid means of improving aerobic capacity (Velasquez & Wilmore, 1992; Williford et al., 1995).

A position paper by the American College of Sports Medicine (ACSM) on the recommended quantity and quality of exercise for developing cardiorespiratory fitness (1990) points out that intensity is one of the critical factors for achieving cardiorespiratory or aerobic fitness. This position paper recommends a training intensity of 50% to 80% of maximal oxygen uptake to develop and maintain aerobic capacity.

A strength of bench aerobics is that participants of varying aerobic fitness levels can be accommodated in the same class, because the aerobic requirement of bench stepping can be tailored to the individual. Factors that can affect the aerobic requirement of bench stepping include body weight (Nagle, Balke, & Naughton, 1965; Stanforth & Stanforth, 1993), bench height (Nagle et al., 1965; Olson, Williford, Blessing, & Greathouse, 1991; Stanforth & Stanforth, 1993; Woody-Brown, Berg, & Latin, 1993), stepping rate (Nagle et al., 1965; Stanforth & Stanforth, 1993), stepping pattern (Olson et al., 1991), and use of hand-held weights (Olson et al., 1991; Goss et al., 1989). By varying these factors individuals can adjust their workouts to their personal aerobic fitness levels.

A potential method for altering the aerobic requirement of bench stepping which has not been studied previously is the effect of adding external weight to the torso. It is known that the aerobic requirement of bench stepping increases with increased body weight (Nagle et al., 1965; Stanforth & Stanforth, 1993), but the effect of adding external weight to the torso during bench stepping is unknown. If adding external weight to the torso is an effective method for altering the energy cost of bench stepping, this will give participants in bench aerobics another method for varying the workout intensity. Therefore, the purpose of this study was to determine the effect of adding external weight to the torso on the aerobic requirement of bench stepping and to compare it with other methods for altering the aerobic requirement of bench stepping.

Method

Participants

Twenty-six healthy women (M age = 23.1 years, SD = 4.2; M height = 163.1 cm, SD = 5.4; M body mass = 57.6 kg, SD = 5.6; and M relative body fat = 21.9%, SD = 5.3), volunteered to participate in this study. All participants gave written informed consent prior to participating in this study. All had participated in bench aerobics at least three times a week for a minimum of two months prior to the study.

Apparatus

The apparatus used included industry standard benches commonly used in bench aerobics classes at three heights (15.2, 20.3, and 25.4 cm). Standard scuba weights (1.35 kg each) and belt were worn around the waist to add external weight. Three different belts with two, four, and six 1.35 kg weights provided external weights of 2.7, 5.4, and 8.2 kg, respectively. These are

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readily available for purchase and relatively easy for participants to put on and remove. A prerecorded tape at 120 beats per minute (bpm) kept participants stepping at the correct cadence.

Oxygen uptake (VO₂) was measured using a SensorMedics 2900 Metabolic Measurement Cart (Sensor Medics Corporation, Yorba Linda, CA). The gas analyzers were calibrated before and after each test with room air and two calibration gases with O₂/CO₂ concentrations of 16.10%/4.00% and 26.00/0.00%. The flow meter was calibrated at the start of each testing day using a calibrated 3.0 liter syringe. Heart rate (HR) was recorded using a Polar CIC, Inc., heart watch (Polar USA, Inc., Montrvale, NJ). Body composition was assessed using hydrostatic weighing as described by Behnke and Wilmore (1974). The equation developed by Siri (1961) was used to convert body density to relative body fat. Residual volume was measured out of water in a seated position using the simplified nitrogen dilution technique (Wilmore, Vodak, Parr, Girandola, & Billing, 1980).

Hydrostatic weighing was conducted in a redwood tub (height = 5 ft, diameter = 6 ft) with a chair made from PVC suspended from a 15-kg Chatillon autopsy scale. Residual volume was measured using a Beckman OM-11 oxygen analyzer, LB-2 carbon dioxide analyzer, and a 5-liter anesthesia bag.

**Design and Procedure**

Participants completed a discontinuous protocol of three sets of bench stepping at 30 step cycles/min¹ (120 bpm). Participants rested in a sitting position for 15 min between each set. Bench height was increased by 5.1 cm for each set (Set 1 = 15.2 cm; Set 2 = 20.3 cm; Set 3 = 25.4 cm). During each 16-min set, participants wore a scuba belt around the waist, and 2.7 kg were added every 4 min (0–4 min = body weight [BW] only; 4–8 min = BW + 2.7 kg; 8–12 min = BW + 5.4 kg; and 12–16 min = BW + 8.2 kg). Thus, a 3 x 4 (Bench Height x External Weight) within-participants design was employed. The three sets were averaged to produce one score for each participant.

Ideally, bench heights would have been assigned randomly and the three sets conducted on separate days. The current design was employed so that each participant could be tested in one session. A similar design has been used in previous bench stepping research (Nagle et al., 1965; Stanforth & Stanforth, 1995). Although no measures were used to determine the level of recovery between sets, a 15-min rest was considered sufficient, because the work rate was moderate (average ratings of perceived exertion [RPE] = 14; and respiratory exchange ratio [RER] = .85 at the highest level of work), and each succeeding set was at a higher work rate.

The stepping cycle consisted of stepping up to full, controlled extension, placing both feet on top of the bench, and stepping down. To avoid fatiguing one leg, participants alternated lead legs with each step cycle by tapping the floor on the fourth beat, performing an “up-up-down-touch” stepping pattern. The stepping rate was regulated at 120 footstrikes·min⁻¹ using a prerecorded metronome tape. The investigators made certain that the participants were in step with the metronome tape at all times. Participants kept their hands on their hips throughout each set.

VO₂ and VCO₂ were measured continuously, and 1-min values were recorded. Heart rate (HR) was recorded during the last 10 s of each minute. Because it has been shown previously that steady state was attained within 2 min during a progressive bench stepping test with increasing workloads of one MET every 5 min (Nagle et al., 1965), data used for analyses were the means of the last 2 min of each 4-min segment.

To determine the reliability of the testing protocol, 6 participants repeated the same testing protocol on another day. A 2 x 3 x 4 (Test x Bench Height x External Weight) repeated measures analysis of variance (ANOVA) determined there were not significant main effects or interactions. Therefore, the remaining participants completed the testing protocol once, and the results from the first day of testing were used for analyses with these 6 participants.

**Data Analysis**

Separate 3 x 4 (Bench Height x External Weight) repeated measures ANOVA's were used to determine if VO₂ and HR varied significantly with different bench height and external weight conditions (p < .05). Magnitude of significant effects was assessed using omega-squared (ω²).

**Results**

For VO₂ (l·min⁻¹), the analysis revealed main effects for bench height, F(2, 50) = 925.9, p < .0001, and external weight, F(3, 75) = 343.2, p < .0001. There was a significant interaction effect between bench height and external weight for VO₂, F(6, 150) = 3.5, p < .05. The ω² revealed that bench height accounted for 57% of the explained variance, external weight for 42%, and the interaction for less than 0.5%. Table 1 shows that VO₂ increased with increases in bench height and external weight. Figure 1 gives the mean VO₂ at each external weight condition.

For HR, the analysis revealed main effects for bench height, F(2, 50) = 343.5, p < .0001, and external weight, F(3, 75) = 199.4, p < .0001. There was a signifi-
cant interaction effect between bench height and external weight for heart rate, $F(6, 150) = 2.36, p < .05$. The $\omega^2$ revealed that bench height accounted for 44% of the explained variance, external weight for 31%, and the interaction for 0.5%. Table 1 shows that HR increased with increases in bench height and external weight. Figure 1 gives the mean HR values at each external weight condition.

**Discussion**

The aerobic requirement of bench stepping increased with increases in both bench height and external weight. In this study, $\text{VO}_2$ increased with an increase in external weight; in other bench stepping studies $\text{VO}_2$ increased with an increase in body weight. For each kilogram of external weight added in this study, $\text{VO}_2$ increased by $\text{Mml/min}^1 = 18.6$, $SD = 1.2$, $Mml/min^2 = 20.6$, $SD = 1.6$, and $M ml/min^3 = 24.8$, $SD = 1.6$, at bench heights of 15.2, 20.3, and 25.4 cm, respectively. At these same bench height and stepping rate combinations, each kilogram increase in body weight increased $\text{VO}_2$ by 21, 25, and 29 ml-min$^{-1}$ in studies by Nagle et al. (1965) and Stanforth & Stanforth (1993).

The increase in $\text{VO}_2$ and HR at the same rate under all conditions indicates that the $\text{VO}_2$/HR relationship of bench stepping was maintained despite the addition of external weight. This strengthens the contention that the aerobic requirement of bench stepping is affected by adding external weight to the torso as if it were additional body weight.

Results from this study and the equation for bench stepping developed by Nagle et al. (1965) and published by the ACSM (Mahler, Froelicher, Miller, & York, 1995) indicate that increasing external weight by about 1.8 kg elicits an increase in $\text{VO}_2$ similar to increasing bench height by 1 cm or stepping rate by 1 step cycle-min$^{-1}$. Olson et al. (1991) determined that using 0.91 kg hand weights increased $\text{VO}_2$ by 0.21-l-min$^{-1}$ during a bench aerobics routine performed at 120 footstrikes-min$^{-1}$ using a 20.3 cm bench. At a bench height of 20.3 cm, adding 9.7 kg of external weight to the torso would be necessary to increase the $\text{VO}_2$ by 0.2 l-min$^{-1}$ in the current study.

The metabolic equivalent (MET) levels achieved in this study range from 6–9.5 METs. This range is similar to values shown previously for low- and high-impact aerobics (Bell & Bussey, 1994; Berry, Cline, Berry & Davis, 1992; Carroll, Otto, & Wygand, 1991; Williford, Olson, & Blessing, 1989) and bench aerobic routines (Olson et al., 1991; Woodby-Brown et al., 1993). The lower end of the MET level achieved in this study (6 METs) is similar to walking 4 mph up a 4% grade (Mahler et al., 1995) and stationary cycling at 85 W (Mahler et al., 1995). The

![Figure 1. Oxygen uptake and heart rate at four external weight conditions. BW = body weight.](image)

| Table 1. Means (± standard deviations) for oxygen uptake (\(\text{VO}_2\)) and heart rate (HR) at three bench height and four external weight conditions |
|---|---|---|---|---|
| **Bench height** | **Variable** | **BW** | **BW + 2.7 kg** | **BW + 5.4 kg** | **BW + 8.2 kg** |
| 15.2 cm | $\text{VO}_2$ | 1.20 ± 0.13 | 1.27 ± 0.14 | 1.30 ± 0.14 | 1.35 ± 0.10 |
| | HR | 123.50 ± 15.70 | 129.30 ± 15.20 | 132.30 ± 15.60 | 135.70 ± 15.10 |
| 20.3 cm | $\text{VO}_2$ | 1.45 ± 0.15 | 1.50 ± 0.15 | 1.55 ± 0.16 | 1.62 ± 0.16 |
| | HR | 136.90 ± 15.90 | 141.90 ± 17.70 | 144.80 ± 17.10 | 149.40 ± 18.60 |
| 25.4 cm | $\text{VO}_2$ | 1.70 ± 0.17 | 1.78 ± 0.19 | 1.83 ± 0.18 | 1.91 ± 0.19 |
| | HR | 151.00 ± 17.70 | 157.40 ± 19.10 | 161.00 ± 19.10 | 166.30 ± 19.10 |

*Note. BW = body weight.*

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upper end of the MET level achieved (9.5 METs) is similar to running at 5.5 mph (Mahler et al., 1995) and stationary cycling at 85 W (Mahler et al., 1995). The upper end of the MET level achieved (9.5 METs) is similar to running at 5.5 mph (Mahler et al., 1995) and stationary cycling at 140 W (Mahler et al., 1995).

The current study examined only the basic march of bench stepping (up, up, down, touch) and did not consider the effect of external weight on different stepping, traveling patterns, or both. The conclusions can be applied only to this stepping pattern.

In summary, adding external weight to the torso increases the aerobic requirement of bench stepping. Using data from this and previous studies, it appears that adding about 20 lb of external weight to the torso is equivalent to increasing bench height by 2 in, increasing music speed by 20 beatsmin⁻¹ or adding 24 lb hand weights.

References


Authors’ Note

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