ABSTRACT

THE EFFECTS OF A SHORT-TERM BACKWARDS RUNNING PROGRAM ON AEROBIC CAPACITY, EQUILIBRIUM, AND PHYSIOLOGIC NOVELTY OF TASK

by Michelle J Pesek

Backward running (BR) is commonly used in sport conditioning, for motor learning and neurological purposes, and even more commonly in physical rehabilitation. The current study investigated the effects of a three week backwards running program on cardiorespiratory fitness, equilibrium, and physiologic novelty of task. Eight (n = 8) male and female college students participated in the study. Subjects were randomly assigned to either a backwards running group (BG) (n = 4) or a no backward running group (NBG) (n = 4). All subjects underwent both forward and backward maximum oxygen consumption testing (V02 max) with lactate readings and balance testing on a force plate in week 0 (pre-intervention) and week 5 (post intervention). Additionally, within the BG, average daily heart rates and speed of sessions were recorded daily during the backwards program to assess physiologic novelty of task. No significant improvements were found in cardiorespiratory fitness as evident in both backward and forward V02 max tests following the three week backward running program. Overall, regardless of the time tested, subjects in the NBG exhibited more time farther away from their mean center of pressure when swaying in the medial-lateral (M-L) axis while standing on the right leg only. All subjects showed a decrease in equilibrium from pre to post tests when standing on the left leg only in the M-L axis. Overall, trends were seen for increased cardiorespiratory fitness and equilibrium with backwards training. Furthermore, it is seen that constant adjustment is needed with backwards programs as it is proposed novelty begins to decrease in as little as one week.
THE EFFECTS OF A
SHORT-TERM BACKWARDS RUNNING PROGRAM ON AEROBIC CAPACITY, EQUILIBRIUM, AND PHYSIOLOGIC NOVELTY OF TASK

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by

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Acknowledgements

The author would like to extend a special thanks to Dr. Mark Walsh for his extensive time and support intellectually with the study, Dr. Rose Marie Ward for her expertise in statistics and constant support through the research process, Dr. Ronald Cox for his continuous encouragement of the research idea and help with study design, Miami University for the equipment and means to make this study possible, and last but not least the participants of this study for their extensive time and enthusiasm for this research.
The Effects of a Short-term Backwards Running Program on Aerobic Capacity, Equilibrium, and Physiologic Novelty of Task

Introduction

Forward (FM) forms of locomotion such as walking and running have been used repeatedly by rehabilitation and fitness professionals in efforts to improve or maintain levels of cardiorespiratory health in addition to aiding in physical therapy. However, since the 1980s, backwards locomotion (BM) has been increasingly gaining popularity especially in physical therapy and sport conditioning. Most commonly, BM has been cited for use in prevention and treatment of patellofemoral knee joint (PTFJ) injuries. Studies note that the unique movement by the knee extensors during slow BM allows a later peak of PTFJ compressive force, compared to FM at the same speeds, which may have a safe-guarded effect on the knee joint (Devita and Stribling, 1991; Grasso et al., 1998; Sussman et al., 2000). Furthermore, Flynn and Soutas (1995) studied the PTFJ compressive forces of healthy recreational runners during backward running (BR) in particular. They reported an absence of rapid knee flexion, commonly seen during forward running (FR). It is suggested that this decrease in rapid loading of the knee flexors is the mechanism behind the lower PTFJ compressive forces during BR and thus, the reduced susceptibility to injury of the PTFJ (Flynn & Soutas, 1995). More recently, BM has even been cited as a means to significantly enhance cognitive performance and control when compared to FM and sideways motion (Koch et al., 2009). From these findings, it has therefore been suggested that BM may be a means to being able to deal with a difficult situation effectively (Koch et al., 2009). Lastly, BM is often used in athletic conditioning in sports such as basketball, soccer, and boxing. In coincidence, a previous study utilizing BM training drills in sport conditioning for athletes reported that BM training caused significantly greater improvements in agility as compared to forward running training drills (Terblanche & Venter, 2009). This fosters the idea for use of BM training in conditioning for that vast majority of sports where agility is of importance.

Besides BM’s benefits in PTFJ rehabilitation and sport conditioning, the effects of BM on cardiorespiratory and metabolic variables have been documented in a vast majority of the BM research. Some of the primary factors indicating aerobic fitness have been suggested to include maximum oxygen consumption (VO2 max), maximum heart rate (HR max), and blood lactate
concentrations. Professional health organizations have cited that 50-85% of VO2 max needs to be maintained in an aerobic exercise bout in order to improve or maintain cardiorespiratory fitness (Pollack et al., 1998). In coincidence, research has found that BM can achieve the above mentioned levels at slower speeds and a lower grade than FM (Chaloupka et al., 1997; Flynn et al., 1994). This knowledge may imply decreased risk for injury (Flynn et al., 1994).

Additionally when evaluating HR max (estimated with an age-predicted equation, 220-age), BM at different grades has demonstrated greater or increased percent of HR max and percent of VO2 max values than FM (Flynn et al., 1994; Hooper et al., 2004). Furthermore, blood lactate concentrations have also lead professionals to believe BM may offer greater or just as many benefits than FM. With regards to the measurement of blood lactate levels, as the respiratory exchange ratio (RER) and the volume of air expired or ventilation (VE) increase in BM, blood lactate levels also increase greatly compared to FM (Flynn et al., 1994, Terblanche et al., 2003).

Therefore, if sustained over a longer session of an aerobic exercise bout, BM has potential to greatly improve lactate tolerance or increase what is called the lactate threshold (the amount of lactate build-up an individual can withstand or utilize by the body’s energy cycle before a significant increase occurs, causing detriments in performance). Lastly, Flynn et al. (1994) stated that BM elicits approximately 30% more metabolic energy than FM at the same speed. Even more, many studies are in agreement that this increased energy expenditure is likely due to the unique increased stride rate and decreased stride length that accompanies BM (Cavagna et al., 2011; Devita & Stribing, 1991; Flynn et al., 1994; Threlkeld et al., 1989; Williford et al., 1998; Wright & Weyand., 2001). Overall, BM’s ability to elicit greater increases (than FM at similar speeds) in heart rate, oxygen consumption, blood lactate, and energy expenditure implies its utilization in fitness and rehabilitation programs in order to maintain or improve aerobic and endurance performance while decreasing risk for injury.

In addition to the increased stride rate and stride frequency of BM, another noted factor leading to the increase in energy utilization observed in BM is the physiologic novelty of the task. For many individuals, BM is not a usual activity that is performed frequently as is FM; therefore, like many novel activities BM causes certain physiological functions to occur to allow such an awkward task to be performed. Research has suggested that the novel task of BM may require increasingly greater or a larger number of motor unit recruitment (Flynn et al., 1994; Hooper et al., 2004). Furthermore, a study by Childs et al., (2002) which initiated a six week
backward walking program, reported that between weeks four and six participants’ initial backwards speeds had to be increased by approximately 14% in order to elicit the same oxygen uptake as in previous weeks. They attribute this finding to the novelty of such a task as BM, in that with repeated bouts of training a motor learning effect occurs allowing the body to recruit motor units for the task more efficiently thus decreasing the novelty of the movement. In general, it is suggested that because backwards locomotion is such an overwhelmingly awkward motion for the body to perform, the previously mentioned motor learning effect is prolonged more than usual (Childs et al., 2002). However, it must be noted that the above investigation only re-evaluated subjects every two weeks, suggesting that perhaps reductions in novelty of BM may have actually been seen in weeks 0-2 or 2-4 in which subjects were not evaluated (Childs et al., 2002). Moreover, almost all studies on BM (including the previous mentioned one) utilized at least one session of familiarization with BM before beginning data collection; making it hard to determine if even one bout of exposure could lessen the novelty of task for BM (Cavagna et al., 2011; Chaloupka et al., 1997; Childs et al., 2002; Flynn et al., 1994; Hooper et al., 2004; Whitley & Dufek., 2011; Williford et al., 1998).

Lastly, BM has been modestly suggested in previous literature to lead to improvements in balance or equilibrium. Previously, the majority of the research has suggested specifically BM’s role in improving muscle balance such as aiding in strengthening the hamstrings so that they can help support the knee joint in motion; which in turn prevents many injuries that come from having an imbalance between the quadriceps and the hamstrings (Bates & McCaw, 1998; Whitley & Dufek, 2011). Even more, although improvement in balance specifically with regards to such termed equilibrium that requires hearing and vision components has been noted in scholarly literature, it seems that such a research study supporting this idea is not readily available to be reviewed.

In general, very few studies have examined the effects of specifically a BR program on cardiorespiratory and metabolic variables. Additionally, while reports have been made there is a lack of supporting research linking BM and changes in equilibrium. Furthermore, additional research is warranted for better describing the time period in which the physiologic novelty of task in BM begins decreasing. Therefore, the purposes of this study are to: 1.) Identify the effects of a three week BR program on cardiorespiratory and metabolic variables, 2.) Distinguish the
effects of a three week BR program on equilibrium, and 3.) Quantify the adaptation period to BR as measured by reduction in physiologic novelty of task. Results from this research, may then be used in better prescribing a BR training program for healthy and injured individuals alike and allow for appropriate adjustments to be made to continue to improve and maintain benefits over time.

Methods

Study Participants

Subjects were recruited from the general student population at Miami University of Ohio via word of mouth, mass emailing to accessible email distribution lists, and visual advertisements. All potential subjects were first screened for inclusionary and exclusionary criteria. Inclusionary criteria included an age of 18 years or older and the ability to run 15 minutes continuously due to time constraints not allowing for acclimization to running. Exclusionary criteria included those who exhibited two or more coronary heart disease (CHD) risk factors on the health history questionnaire (see Appendix A), use of any medications (e.g. insulin, bronchodilators) that could affect physical performance or metabolism, those with any metabolic disease that would affect energy metabolism (e.g. diabetes), current smokers, those who had experience with backwards running, and those with any current orthopedic problems that would inhibit participation in exercise testing and the exercise program.

Eight subjects, four females and four males with a mean (± SD) age of 22± 1 year, met the inclusionary and exclusionary criteria and volunteered to participate in the study. Physical characteristics (mean ± SD) included mass of 70±17 kg, height of 170± 8 cm, and Body Mass Index (BMI) of 24 ± 4 kg/m². Table 1 presents a summary of descriptive data for the treatment group, non-treatment group, and the total sample. All subjects except one reported engaging in regular, moderate to high aerobic activity. The subject who did not engage in regular moderate aerobic activity reported engaging in regular anaerobic activity such as strength training. All participants completed an exercise participation questionnaire (see Appendix B) and an informed consent form prior to participation in the study (see Appendix C). The study was approved by the Institutional Review Board of Miami University.
Study Design

A repeated measure experimental design was used in this study to determine if participants’ equilibrium, cardiorespiratory measures, and metabolic measures would change from before the three week intervention period to after the three week intervention period depending on if they participated in the backwards running program or not. The independent variable of the study was therefore the backwards running program. Equilibrium dependent variables (measured in mm) included the difference in maximum and minimum postural sway of the x (medial-lateral (M-L)) and y (anterior-posterior (A-P)) axes, mean postural sway of the x and y axes, and standard deviation of postural sway in the x and y axes. Cardiorespiratory and metabolic dependent variables included forwards V02 max and backwards V02 max values reported in both absolute and relative terms. Within each max test, further dependent variables included RER, VE, HR max, and blood lactate levels. In addition, time lasted in pre and post backwards max tests and percent of forward V02 max (in relative terms) and HR max able to achieve in backwards max tests were also analyzed. To assess possible changes due to the three week backwards running program, study participants were randomly assigned to either a control (no backwards running program, (NBG)) group (n = 4) or an experimental (backwards running program, (BG)) group (n = 4).

To determine changes in physiologic novelty of task within the backwards running group, a single-group repeated measures design was utilized. The independent variable for the novelty portion of this experiment was time, reported in days. The dependent variables for assessing

<table>
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<th>Height(cm)</th>
<th>Mass (kg)</th>
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<tr>
<td>no treatment</td>
<td>Mean 21.750</td>
<td>24.750</td>
<td>173.1875</td>
<td>74.7700</td>
</tr>
<tr>
<td></td>
<td>N 4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation 1.2583</td>
<td>6.0611</td>
<td>10.15582</td>
<td>22.48509</td>
</tr>
<tr>
<td>treatment</td>
<td>Mean 21.500</td>
<td>23.225</td>
<td>166.5250</td>
<td>64.6600</td>
</tr>
<tr>
<td></td>
<td>N 4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation 1.0000</td>
<td>2.3641</td>
<td>3.40135</td>
<td>9.19112</td>
</tr>
<tr>
<td>Total</td>
<td>Mean 21.625</td>
<td>23.988</td>
<td>169.8563</td>
<td>69.7150</td>
</tr>
<tr>
<td></td>
<td>N 8</td>
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<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation 1.0607</td>
<td>4.3364</td>
<td>7.86409</td>
<td>16.79537</td>
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</tbody>
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Table 1: Descriptive data for the no treatment group (n = 4), treatment group (n = 4), and the total sample (n = 8).
novelty of task included average running session heart rate given in beats per minute (bpm) and running session speed given in meters per second (m/s).

Procedure

In the pre-intervention period (week 0), each subject first underwent equilibrium testing followed by their first V02max test with lactate testing on the same day. On a non-consecutive day, their other V02 max in the opposite direction with lactate testing was carried out. Upon completion of the second max test, subjects were randomly assigned either the treatment (BG) or non-treatment group (NBG). The treatment group then completed the backwards running program over the following three weeks while the non-treatment group did not participate in the program. Furthermore, the non-treatment group was instructed to not perform BM in the following three weeks. All subjects were also instructed to continue their usual workout routine without increasing or reducing any component of it. Post-tests were then carried out during the post-intervention period (week 4) following the same procedure as pre testing. In addition, all participants were then asked to fill out a brief post-study questionnaire asking about their experience with backwards running (see Appendix D).

Measures

Equilibrium Testing. Equilibrium or postural sway was measured in the Motor Behavior Laboratory utilizing a Bertec Force Plate AM 6511 (Bertec Corporation, Columbus, OH). Each subject performed a four condition standing balance test on the force plate. The four conditions were as follows: 1.) Stand on both legs with eyes closed, 2.) Stand on both legs with eyes opened, 3.) Stand on left leg with eyes opened, and 4.) Stand on right leg with eyes opened. For the two double leg conditions, participants stood barefoot with the lateral edges of their feet 18.5 inches apart (based on the average shoulder width stance of the participants). In addition, subjects were instructed to cross their arms over their chest, stare straight ahead, do not talk, and to minimize all bodily movement. For the one-legged conditions they were further instructed to flex the opposite leg to a 90 degree position and to not let their two legs touch. Re-trials were carried out when any of the previous instructions were not met. All conditions were held for 30 seconds. Testing order of the four conditions was randomized for the pre-tests and then held constant for the post tests. From this data and for both the A-P and M-L axes, maximum and minimum difference (range) of postural sway, mean postural sway, and standard deviation of postural sway were calculated and recorded.
**V02 Max Testing.** V02 max testing was conducted in the Exercise Science Fitness Laboratory. Each subject completed both forward and backward V02 max tests pre and post intervention period. In order to deem a valid V02 max had been reached, three of the following four criteria had to be met: 1.) Plateau (no change in V02 greater than ±1-2 ml·kg·min with an increase in workload) of relative V02, 2.) ±10 beats per minute (bpm) of age-predicted HR max, 3.) Borg Rating of Perceived Exertion (RPE) (see Appendix E) of at least 18, and 4.) RER of 1.10 or higher. For the forward max test, subjects were asked to describe a typical speed they would use to run on a treadmill or how long it typically takes them to complete a mile run. This information was then used as the constant speed for both their pre and post forward max tests. For all forward max tests, subjects ran at a constant speed (mean 2.82 ± .16m/s, range 2.68-3.13 m/s) with no grade for the first two minutes, from there on grade was increased by 2.5% every two minutes until volitional fatigue. In conducting the backward max tests, subjects were asked to walk backwards on the treadmill until they felt comfortable. Once the subject was able to perform backwards walking without holding on, the investigator slowly increased the speed until a running pace was achieved that the subjects felt they could maintain. This process was carried out within five minutes for all subjects to minimize exposure and familiarization to backwards running. The backwards running pace determined from the above process was then used as the constant speed (mean 2.24 ± .26 m/s, range 1.43-2.24 m/s) for both their pre and post backwards max tests. For all backwards max tests, subjects ran at a constant speed with no grade for the first two minutes, from there on grade was increased by 2% every two minutes until volitional fatigue. Backwards and Forwards V02 max testing was completed for each subject on two non-consecutive days in both the pre-intervention week (week 0) and the post-intervention week (week 4). The testing order (backwards or forwards) was randomized for the pre tests and then held constant for the post tests. During all max tests, subjects breathed through a two-way nonrebreathing valve and expiratory gases were collected via a gas chamber analyzer (Hans Rudolph, Inc, Shawnee, KS). A computer program (Parvomedics True One 2400 Metabolic Measurement System, Sandy, Utah) then performed calculations of breath by breath oxygen consumption, VE, carbon dioxide production (VC02), and other cardiorespiratory measurements.

**Blood Lactate Testing.** Before and after each V02 max test, the subject was also tested for lactate levels in the blood utilizing a Lactate Scout meter (SensLab GmbH, Leipzig, Germany). A minuscule amount of blood was drawn via a finger prick by a gloved investigator after five minutes of seated rest prior to the V02 max tests and one minute after completion of the V02 max tests. All lactate
testing was conducted utilizing the Infectious Waste Management Guidelines as stated by the Laboratory Procedures established by the Department of Kinesiology and Health (see Appendix F).

**Backwards Running Program**

The backwards running group (n = 4), ran backwards on a treadmill for five self-selected days of the week for a total of three consecutive weeks or more specifically 15 sessions. A primary investigator supervised all sessions. Each session consisted of two ten minutes bouts of backwards running with a five minute walk break in between bouts performed at .67 m/s. Subjects ran backwards at a vigorous intensity (77-95% of HR max), with the lower end of the vigorous intensity range being the aim. Speed was adjusted daily as needed to achieve this minimum vigorous intensity level. Speed over the course of the program between all subjects ranged from 1.34-2.10 m/s. Heart rate was measured utilizing PolarFTI heart rate monitors (Polar Electro, Kempele, Finland).

**Statistical Analyses**

Descriptive statistics were generated for the total sample (n = 8) utilizing IBM’s *Statistical Package for Social Sciences (SPSS) 20.0 version*. To test randomization or that groups were similar regarding age, height, weight, and BMI, a series of independent t-tests were run. The independent t-tests conducted, comparing the two groups on all the previously mentioned characteristics, showed no significant group differences (p > .05). Next, to determine if participants varied significantly on their measures of cardiorespiratory and balance variables between the BG and NBG and to investigate if there was significant differences within variables of each group from pre to post tests, a series of 2X2 (Treatment Condition (NBG versus BG) x Time (baseline versus post-test)) mixed between-within subjects analyses of variance (ANOVAs) were conducted. Additionally, to evaluate differences in physiologic novelty of task variables in the BG, a scatter plot was configured and after visual inspection for trends multiple paired samples t-tests were carried out checking for significant changes in speed and heart rate day to day. For all analyses, alpha level was accepted at the p < .05 level of significance.
Results

Cardiorespiratory and Metabolic Variables

Table 2 shows a comparison of all cardiorespiratory variables analyzed for forward max tests and Table 3 shows a comparison of all cardiorespiratory variables for backwards max tests.

Table 2: Comparison of cardiorespiratory variables measured during pre and post FORWARD max tests (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>NBG Pre</th>
<th>NBG Post</th>
<th>BG Pre</th>
<th>BG Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO(_2), ml·kg(^{-1})·min(^{-1})</td>
<td>49.05 ± 8.03</td>
<td>50 ± 9.54</td>
<td>42.6 ± 3.99</td>
<td>42.93 ± 5.32</td>
</tr>
<tr>
<td>VO(_2), l·min(^{-1})</td>
<td>3.64 ± 1.07</td>
<td>3.73 ± 1.02</td>
<td>2.76 ± .53</td>
<td>2.82 ± .70</td>
</tr>
<tr>
<td>VE, l·min(^{-1})</td>
<td>120 ± 47.58</td>
<td>116.47 ± 44.66</td>
<td>92.79 ± 27.93</td>
<td>91.41 ± 35.01</td>
</tr>
<tr>
<td>RER</td>
<td>1.12 ± .10</td>
<td>1.10 ± .03</td>
<td>1.14 ± .03</td>
<td>1.10 ± .03</td>
</tr>
<tr>
<td>HR max, beats·min(^{-1})</td>
<td>191 ± 1</td>
<td>190 ± 10</td>
<td>198 ± 3</td>
<td>197 ± 2</td>
</tr>
<tr>
<td>Lactate (Post – Pre), mmol·l(^{-1})</td>
<td>9.85 ± 4.42</td>
<td>9.3 ± 1.06</td>
<td>8.03 ± 1.80</td>
<td>8.58 ± 1.36</td>
</tr>
<tr>
<td>RPE</td>
<td>18 ± 1</td>
<td>17 ± 1*</td>
<td>19 ± 1</td>
<td>18 ± 1*</td>
</tr>
</tbody>
</table>

* P< .05 for main effect for Time

Table 3: Comparison of cardiorespiratory variables measured during pre and post BACKWARDS max tests (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>NBG Pre</th>
<th>NBG Post</th>
<th>BG Pre</th>
<th>BG Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO(_2), ml·kg(^{-1})·min(^{-1})</td>
<td>40.95 ± 5.39</td>
<td>41 ± 6.24</td>
<td>32.7 ± 4.11</td>
<td>35.5 ± 2.62</td>
</tr>
<tr>
<td>VO(_2), l·min(^{-1})</td>
<td>3.01 ± .68</td>
<td>3.05 ± .75</td>
<td>2.27 ± .46</td>
<td>2.32 ± .43</td>
</tr>
<tr>
<td>VE, l·min(^{-1})</td>
<td>97.16 ± 38.02</td>
<td>103.12 ± 36.44</td>
<td>79.53 ± 23.1</td>
<td>79.20 ± 27.41</td>
</tr>
<tr>
<td>RER</td>
<td>1.10 ± .04</td>
<td>1.09 ± .05</td>
<td>1.13 ± .05</td>
<td>1.11 ± .07</td>
</tr>
<tr>
<td>HR max, beats·min(^{-1})</td>
<td>184 ± 10</td>
<td>187 ± 13</td>
<td>187 ± 11</td>
<td>191 ± 10</td>
</tr>
<tr>
<td>Lactate (Post – Pre), mmol·l(^{-1})</td>
<td>6.98 ± 1.8</td>
<td>6.3 ± 1.06</td>
<td>5.8 ± 3.57</td>
<td>5.63 ± 2.64</td>
</tr>
<tr>
<td>RPE</td>
<td>18 ± 2</td>
<td>19 ± 1</td>
<td>17 ± 3</td>
<td>19 ± 1</td>
</tr>
</tbody>
</table>

\(V_0^2\) max

The results of the 2X2 (Treatment Condition x Time) mixed ANOVA for the forward \(V_0^2\) max in relative terms (ml/kg/min) revealed no significant main effects for Time \((p = .44)\) or Treatment Condition \((p = .22)\). Additionally, no significant interaction effect was found \((p = .70)\). Results of the 2X2 ANOVA for the forward \(V_0^2\) max in absolute terms (L/min) showed no significant main effects for Time \((p = .32)\) or Treatment Condition \((p = .18)\). The interaction effect was also found to be non significant \((p = .84)\).

The 2X2 mixed ANOVA results for backwards \(V_0^2\) max in relative terms showed no significant main effect for Time \((p = .259)\) and no significant interaction effect \((p = .274)\). The
main effect for Treatment Condition approached significance, \( F (1) = 4.65, p = .07 \), eta squared = .44. The ANOVA results for the backwards V02 max in absolute terms showed no significant main effect for Time \( (p = .28) \) or Treatment Condition \( (p = .13) \). No significant interaction effect was found either \( (p = .97) \).

**Max VE**

Results from the mixed ANOVA for max VE during forward max tests revealed no significant main effects for Time \( (p = .54) \) or Treatment Condition \( (p = .39) \). Coinciding, no significant interaction effect was found \( (p = .77) \). 2x2 ANOVA results for max VE during backwards max tests showed no significant main effects for Time \( (p = .572) \) or Treatment Condition \( (p = .38) \). The results also revealed no significant interaction effect \( (p = .53) \).

**Max RER**

Reports from the ANOVA for max RER during forward max tests revealed no significant main effects for Treatment Condition \( (p = .89) \) and Time \( (p = .21) \). No significant interaction effect was found either \( (p = .55) \). The 2X2 ANOVA results for max RER during backwards max tests revealed no significant main effects for Time \( (p = .51) \) or Treatment Condition \( (p = .46) \). It was also reported that no significant interaction effect was found \( (p = .79) \).

**HR max**

The results for the 2X2 mixed ANOVA for HR max during the forward max tests showed no significant main effects for Time \( (p = .51) \) or Treatment Condition \( (p = .10) \). Additionally, no significant interaction effect was found \( (p = .86) \). ANOVA results for HR max during the backwards tests yielded no significant main effects for Treatment Condition \( (p = .63) \) or Time \( (p = .11) \). Results also showed that no significant interaction effect was present \( (p = .84) \).

**Blood Lactate Changes from Pre Max Test to Post Max Test**

The results of the 2X2 mixed ANOVA for difference in blood lactate pre to post forward max test revealed no significant main effects for Treatment Condition \( (p = .45) \) or Time \( (p = 1.00) \). It was also reported that there was no significant interaction effect \( (p = .62) \). Results of a mixed ANOVA showed that for difference in blood lactate pre to post backwards max test there were no significant main effects for Time \( (p = .53) \) or Treatment Condition \( (p = .59) \). No significant interaction effects were found either \( (p = .71) \).
Max RPE

The results of a 2X2 ANOVA for max RPE during forward max tests showed no significant interaction effect ($p = .32$). However a significant main effect for Time was found (Wilks' Lambda = .36, $F(1, 6) = 10.57$, $p = .02$, eta squared = .64). When looking at the data, it was shown that from pre forward max tests to post forward max tests, both groups showed significant decreases in the max RPE values they reported. Next, the significant main effect for Treatment Condition approached significance, $F(1) = 4.12$, $p = .09$, eta squared = .41. Results from an ANOVA for max RPE during backward max tests showed no significant main effects for Time ($p = .11$) or Treatment Condition ($p = .58$). Also, no significant interaction effect was revealed ($p = .61$).

Time Lasted in Pre and Posts Backwards Max Tests

The results from the 2X2 mixed ANOVA render no significant main effects for Treatment Condition ($p = .91$). There was a significant main effect found for Time, Wilks' Lambda = .07, $F(1, 6) = 85.47$, $p = .01$, eta squared = .94. Overall, regardless of group, subjects exhibited significant increases in the time they were able to last in the backwards max tests from pre to post tests. In addition, a significant interaction effect was found between Time and Treatment Condition, Wilks’ Lambda = .19, $F(1, 6) = 25.19$, $p = .01$, eta squared = .81. The data shows the time lasted in the backwards max tests, from pre to post, was affected by what Treatment Condition the subject was in. In general, subjects in the BG made more of a significant improvement from pre to post tests and were able to last longer (in minutes) in the backwards max test than subjects in the NBG as shown in Figure 1.

![Figure 1: Mean change from pre to post tests in time lasted in backwards max tests in the NBG (n = 4) and BG (n = 4).](image)
Percent of forward V02 max and HR max (ml-kg-min) able to achieve in backwards max tests

In observation of the data collected, subjects in the NBG were able to achieve an average of 84% of their pre forward V02 max during the pre backwards max test. The BG was able to achieve a mean of 77% of their pre forward V02 in the pre backwards max test. When looking at the post test data, the NBG had a extremely slight decrease and was able to achieve an average of 83% of their forward V02 max during the post backwards max test. Subjects in the BG had a noticeable increase and was able to achieve a mean of 83% of their forward V02 during the post backwards max test. However, the mixed ANOVA revealed no significant Time main effect ($p = .46$), Treatment Condition main effect ($p = .44$), or interaction effect ($p = .25$).

When examining the numbers obtained, those in the NBG were able to achieve an average of 96% of their pre forward HR max during the pre backward max test. Subjects in the BG achieved a mean of 94% of their pre forward HR max during the pre backward max test. The data from the post tests showed that individuals in the NBG reached a mean of 99% of their forward HR max during their post backward max test. Those in the BG were able to achieve an average of 97% of their forward HR max when performing their post backward max test. In statistical analysis, the 2X2 mixed ANOVA showed no significant main effect for Treatment condition ($p = .68$) and no significant interaction effect ($p = .97$). However, a significant main effect for Time was reported, Wilks’ Lambda = .41, $F (1, 6) = 8.79$, $p = .03$, eta squared = .60. Therefore, regardless of Treatment Condition, all subjects showed a significant increase in percent of forward HR max able to achieve in backward max test from pre to post tests.

Equilibrium Variables

Tables 4 and 5 show a comparison of all equilibrium variables analyzed in the M-L axis for pre and post tests in the NBG and BG respectively. Furthermore, Tables 6 and 7 show a comparison of all equilibrium variables analyzed in the A-P axis for pre and post tests in the NBG and BG respectively.
Table 4: Comparison of equilibrium variables measured in the M-L axis during pre and post tests in the NBG (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>2LO</th>
<th>2LC</th>
<th>LL</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of sway, mm</td>
<td>36.18 ± 10.07</td>
<td>36.16 ± 12.82</td>
<td>44.23 ± 11.15</td>
<td>52.25 ± 7.51</td>
</tr>
<tr>
<td></td>
<td>36.30 ± 17.16</td>
<td>44.42 ± 15</td>
<td>77.94 ± 14.67*</td>
<td>69.04 ± 24.94</td>
</tr>
<tr>
<td>SD of sway, mm-sec</td>
<td>6.25 ± 1.51</td>
<td>6.27 ± 2.12</td>
<td>8.34 ± 2.44</td>
<td>9.66 ± 1.82·</td>
</tr>
<tr>
<td></td>
<td>6.22 ± 2.78</td>
<td>6.82 ± 3.00</td>
<td>13.89 ± 3.10</td>
<td>12.43 ± 2.61·</td>
</tr>
<tr>
<td>Mean sway, mm</td>
<td>275.46 ± 40.74</td>
<td>271.53 ± 35.96</td>
<td>294.10 ± 32.67</td>
<td>294.30 ± 36.12</td>
</tr>
<tr>
<td></td>
<td>282.88 ± 52.10</td>
<td>271.18 ± 38.60</td>
<td>310.31 ± 47.37</td>
<td>305.50 ± 32.03</td>
</tr>
</tbody>
</table>

2LO= Two legs, eyes opened, 2LC= Two legs, eyes closed, LL= Left leg, eyes opened, RL= Right Leg, eyes opened.
*P< .05 for main effect for Time
·P< .05 for main effect for Treatment Condition
BOLD= Post Tests Result

Table 5: Comparison of equilibrium variables measured in the M-L axis during pre and post tests in the BG (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>2LO</th>
<th>2LC</th>
<th>LL</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of sway, mm</td>
<td>26.91 ± 3.50</td>
<td>28.77 ± 6.91</td>
<td>50.64 ± 20.90</td>
<td>46.62 ± 16.39</td>
</tr>
<tr>
<td></td>
<td>33.39 ± 16.61</td>
<td>26.07 ± 6.40</td>
<td>69.47 ± 20.39*</td>
<td>41.75 ± 8.37</td>
</tr>
<tr>
<td>SD of sway, mm-sec</td>
<td>4.09 ± .87</td>
<td>5.00 ± 2.06</td>
<td>9.64 ± 5.08</td>
<td>7.30 ± 2.22·</td>
</tr>
<tr>
<td></td>
<td>4.99 ± 2.45</td>
<td>5.67 ± 2.51</td>
<td>10.09 ± 4.98</td>
<td>7.30 ± 1.74·</td>
</tr>
<tr>
<td>Mean sway, mm</td>
<td>287.42 ± 35.05</td>
<td>287.03 ± 31.90</td>
<td>290.68 ± 34.07</td>
<td>294.39 ± 14.04</td>
</tr>
<tr>
<td></td>
<td>280.09 ± 49.75</td>
<td>285.14 ± 47.58</td>
<td>284.15 ± 36.36</td>
<td>290.47 ± 26.80</td>
</tr>
</tbody>
</table>

2LO= Two legs, eyes opened, 2LC= Two legs, eyes closed, LL= Left leg, eyes opened, RL= Right Leg, eyes opened.
*P< .05 for main effect for Time
·P< .05 for main effect for Treatment Condition
BOLD= Post Tests Result

Table 6: Comparison of equilibrium variables measured in the A-P axis during pre and post tests in the NBG (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>2LO</th>
<th>2LC</th>
<th>LL</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of sway, mm</td>
<td>12.97 ± 3.71</td>
<td>12.03 ± 7.39</td>
<td>34.00 ± 6.26</td>
<td>33.55 ± 6.99</td>
</tr>
<tr>
<td></td>
<td>15.41 ± 12.35</td>
<td>13.54 ± 6.05</td>
<td>45.00 ± 11.63</td>
<td>43.75 ± 13.76</td>
</tr>
<tr>
<td>SD of sway, mm-sec</td>
<td>1.67 ± .57</td>
<td>1.49 ± .75</td>
<td>5.80 ± 1.31</td>
<td>5.66 ± 1.21</td>
</tr>
<tr>
<td></td>
<td>2.58 ± 2.35</td>
<td>2.04 ± .86</td>
<td>8.15 ± 2.16</td>
<td>8.38 ± 3.14</td>
</tr>
<tr>
<td>Mean sway, mm</td>
<td>438.55 ± 21.26</td>
<td>444.42 ± 17.00</td>
<td>643.94 ± 10.00</td>
<td>232.30 ± 36.88</td>
</tr>
<tr>
<td></td>
<td>440.97 ± 26.09</td>
<td>440.60 ± 39.11</td>
<td>621.88 ± 30.66</td>
<td>235.39 ± 79.83</td>
</tr>
</tbody>
</table>

2LO= Two legs, eyes opened, 2LC= Two legs, eyes closed, LL= Left leg, eyes opened, RL= Right Leg, eyes opened.
BOLD= Post Tests Result
Table 7: Comparison of equilibrium variables measured in the A-P axis during pre and post tests in the BG (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>2LO</th>
<th>2LC</th>
<th>LL</th>
<th>RL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of sway, mm</td>
<td>13.12 ± 5.37</td>
<td>9.89 ± 4.35</td>
<td>38.52 ± 5.69</td>
<td>34.24 ± 9.03</td>
</tr>
<tr>
<td></td>
<td>12.14 ± 2.71</td>
<td>11.47 ± 4.36</td>
<td>34.62 ± 5.70</td>
<td>35.63 ± 7.93</td>
</tr>
<tr>
<td>SD of sway, mm·sec</td>
<td>1.58 ± .61</td>
<td>1.27 ± .53</td>
<td>6.41 ± 1.36</td>
<td>6.61 ± 2.45</td>
</tr>
<tr>
<td></td>
<td>2.03 ± .50</td>
<td>1.36 ± .64</td>
<td>6.17 ± 1.30</td>
<td>6.09 ± 1.61</td>
</tr>
<tr>
<td>Mean sway, mm</td>
<td>443.80 ± 21.82</td>
<td>439.38 ± 28.76</td>
<td>628.59 ± 46.42</td>
<td>255.90 ± 95.60</td>
</tr>
<tr>
<td></td>
<td><strong>446.18 ± 7.12</strong></td>
<td><strong>444.16 ± 6.70</strong></td>
<td><strong>630.79 ± 22.71</strong></td>
<td><strong>230.14 ± 43.53</strong></td>
</tr>
</tbody>
</table>

2LO= Two legs, eyes opened, 2LC= Two legs, eyes closed, LL= Left leg, eyes opened, RL= Right Leg, eyes opened.

**BOLD**= Post Tests Result

**Range of postural sway along the M-L axis**

Results from the ANOVA for range of postural sway along the M-L axis when standing normally with eyes opened from pre to post tests showed no significant main effects for Treatment Condition ($p = .47$) or Time ($p = .53$). No significant interaction effect was found either ($p = .55$). 2X2 ANOVA results for range of postural sway along the M-L axis from pre to post tests when standing normally with eyes closed revealed no significant Time main effect ($p = .45$), Treatment Condition main effect ($p = .11$), or interaction effect ($p = .16$). A mixed ANOVA for range of postural sway along the M-L axis while standing on the left leg only from pre to post tests showed no significant Treatment Condition main effect ($p = .65$) or interaction effect ($p = .15$). A significant main effect was found for Time, Wilks’ Lambda = .38, $F (1, 6) = 9.67, p = .02$, eta squared = .62. In general, regardless of Treatment Condition, all participants showed a significant increase in range of postural sway in the M-L axis while standing on the left leg only from pre to post tests. More specifically then, all subjects demonstrated more postural sway in the M-L axis while standing on their left leg only during their post tests. Results from an ANOVA for range of postural sway along the M-L axis from pre to post tests while standing on the right leg only showed no significant Time main effect ($p = .51$) or interaction effect ($p = .25$). However, the main effect for Treatment Condition approached significance, $F (1, 6) = 4.95, p = .07$, eta squared = .45.

**Range of postural sway along the A-P axis**

A mixed 2X2 ANOVA for range of postural sway along the A-P axis from pre to post tests when standing normally with eyes opened yielded no significant results for Time main effect ($p = .81$), Treatment Condition main effect ($p = .72$), or interaction effect ($p = .56$).
analysis from a mixed ANOVA for range of postural sway along the A-P axis when standing normally with eyes closed from pre to post tests found no significant Treatment Condition main effect ($p = .60$), Time main effect ($p = .25$), or interaction effect ($p = .98$). The results from the ANOVA for range of postural sway along the A-P axis from pre to post tests when standing on just the left leg, showed no significant main effects for Time ($p = .30$) or Treatment Condition ($p = .46$). However, the interaction effect between Time and Treatment Condition approached significance, $F(1, 6) = 5.14$, $p = .06$, eta squared = .46. Reports from a mixed ANOVA analyzing range of postural sway along the A-P axis from pre to post tests when standing on only the right leg, showed that there were no significant main effects for Treatment Condition ($p = .50$) or Time ($p = .25$). There was also no significant interaction effect found ($p = .37$).

**Standard deviation of postural sway in the M-L axis**

Results from a 2X2 ANOVA analyzing differences in standard deviations of postural sway in the M-L axis from pre to post tests, when standing normally with eyes closed, showed no significant Time main effect ($p = .98$), Treatment Condition main effect ($p = .23$), or interaction effect ($p = .49$). Additionally, an ANOVA for standard deviations of postural sway in the M-L axis when the subject stood normally with eyes opened yielded no significant results for Treatment Condition main effect ($p = .24$), Time main effect ($p = .52$), or interaction effect ($p = .49$). When analyzing the differences in standard deviation of postural sway in the M-L axis while standing only on the left leg with eyes opened, a mixed ANOVA reported no significant Time main effect ($p = .10$), Treatment Condition main effect ($p = .63$), or interaction effect ($p = .14$). Lastly, an ANOVA for difference in standard deviation of postural sway in the M-L axis when standing on the right leg only revealed no significant Time main effect ($p = .23$) or interaction effect ($p = .37$). However, a significant main effect for Treatment Condition was found, $F(1, 6) = 14.77$, $p = .01$, eta squared = .71. In observation of the data, there was a significance difference in standard deviation of postural sway in the M-L axis for those in the NBG group; as they tended to spend more time farther away from their mean center of pressure (COP) along the M-L while standing on the right leg regardless of the time they were tested.

**Standard deviation of postural sway in the A-P axis**

Results of a 2X2 ANOVA for differences in standard deviation of postural sway in the A-P axis while standing normally with eyes closed, showed no significant main effects for Treatment Condition ($p = .34$) or Time ($p = .23$). No significant interaction effect was shown
either \( (p = .39) \). In conjunction, an ANOVA for standard deviation of postural sway in the A-P axis while standing normally with eyes opened found no significant results for Time main effect \( (p = .19) \), Treatment Condition main effect \( (p = .69) \), or interaction effect \( (p = .64) \). Next, a mixed ANOVA for standard deviation of postural sway in the A-P axis when standing on just the left leg yielded no significant Treatment Condition main effect \( (p = .41) \), Time main effect \( (p = .24) \), or interaction effect \( (p = .16) \). Finally, an ANOVA analyzing standard deviation of sway in the A-P axis while subjects stood on the right leg only found no significant results for Time main effect \( (p = .33) \) or Treatment Condition main effect \( (p = .59) \). Also, no significant interaction effect was reported \( (p = .17) \).

### Mean postural sway in the M-L axis

A mixed 2X2 ANOVA for mean postural sway in the M-L axis while standing on two legs with eyes closed revealed no significant Time main effect \( (p = .86) \), Treatment Condition main effect \( (p = .60) \), or interaction effect \( (p = .91) \). When analyzing mean postural sway in the M-L axis while standing normally with eyes opened, an ANOVA showed no significant results for Treatment Condition main effect \( (p = .89) \), Time main effect \( (p = 1.00) \), and interaction effect \( (p = .46) \). When subject stood on their left leg only, a mixed ANOVA analyzing mean postural sway in the M-L axis reported no significant Time main effect \( (p = .59) \), Treatment Condition main effect \( (p = .58) \), or interaction effect \( (p = .24) \). Lastly, an ANOVA for mean postural sway in the M-L axis while standing on the right leg only yielded no significant results for Treatment Condition main effect \( (p = .70) \), Time main effect \( (p = .70) \), or interaction effect \( (p = .42) \).

### Mean postural sway in the A-P axis

An ANOVA for mean postural sway in the A-P axis while standing on two legs with eyes closed uncovered no significant results for Treatment Condition main effect \( (p = .96) \), Time main effect \( (p = .96) \), or interaction effect \( (p = .67) \). A mixed ANOVA for mean postural sway in the A-P axis when subjects stood normally with eyes opened showed no significant main effects for Time \( (p = .60) \) or Treatment Condition \( (p = .72) \). In addition, no significant results were found for interaction effect \( (p = 1.00) \). When analyzing mean postural sway in the A-P axis when standing on the left leg only, a 2X2 ANOVA revealed no significant results for Treatment Condition main effect \( (p = .87) \), Time main effect \( (p = .35) \), or interaction effect \( (p = .26) \). Finally, an ANOVA for mean postural sway in the A-P axis when subjects stood on the right leg...
only showed there was no significant Time main effect ($p = .57$), Treatment Condition main effect ($p = .84$), or interaction effect ($p = .48$).

**Physiologic Novelty of Task Variables**

Figures 2 and 3 show the daily speeds and mean daily heart rates respectively, of all BG subjects’ backwards running sessions over the three week intervention period. In addition, it should be noted that all BG subjects attended at least 85% of the 15 training sessions and only one was able to attend all 15 sessions.

**Figure 2: Daily speeds of backwards running sessions for each subject in the BG (n = 4)**

**Figure 3: Mean daily heart rates of backwards running sessions for each subject in the BG (n = 4)**
Change in daily speed over time

After visual inspection of the scatter plot for group speed trends, a paired samples t-test was conducted to evaluate significant increases in speed from day eight to day nine. The results indicated that the mean speed of day nine (\(M = 1.70, SD = .24\)) was not significantly greater than the mean speed of day eight (\(M = 1.67, SD = .23\)). However, the difference in speed between day eight and day nine did approach significance, \(t(3) = -2.61, p = .08\). The 95% confidence interval for the mean difference between the two days was -0.05 to 0.01. In order, to account for any changes not observed from visual inspection of the scatter plot, multiple paired samples t-tests were conducted between all days. All results showed no significant changes, \(p > .05\).

Changes in mean daily heart rate over time

A possible trend of a decrease in heart rate from day seven to day eight was observable from visual inspection of the scatter plot. However, multiple paired samples t-tests were conducted to account for any significant decreases in heart rate between all days. The results of all paired samples t-tests showed no significant differences between days, \(p > .05\).

Discussion

Previous literature involving BR has investigated mainly acute changes in cardiorespiratory and metabolic variables. Furthermore, very few studies can be found reporting the effects of BR on balance and the amount of time it takes to adapt to BR. Therefore it was the purpose of this study to identify the effects of a longer term BR program on cardiorespiratory and metabolic variables, identify the impact of a BR program on equilibrium, and lastly quantify the adaptation period to the novel motor task of BR.

Past research looking at cardiorespiratory and metabolic effects of BM has noted significant increases in relative V02, VE, RER, HR, and RPE during BM compared to FM at the same speeds (Chaloupka et al., 1997). Even more, increases in relative V02s and HRs have been reported to occur even when comparing slower speeds of BM to higher speeds of FM (Williford et al., 1998). The current study focused on the effects of a training program on the above mentioned variables rather than comparing these variables while looking at effects of FM and BM at similar and different speeds acutely. However, from observing the data collected and seemingly significant differences in self-selected backward and forward max speeds it is
believed that similar results as previous research has implied would have been found if both backward and forward max tests were performed at the same speeds.

In this investigation, it was seen that RPE decreased significantly from pre to post forward max tests for all subjects. It is believed this was a mere result of familiarization to the forward max test procedure and protocol. Overall, no significant changes in V02 max, HR max, VE, RER, or pre to post max test lactate differences were seen after completion of a three week backward running program. However, from observation of the quantitative data, some trends between groups should be noted. Flynn et al. (1994) used a similar backwards and forwards max protocol as the one used in this research and found HR response was not significantly different between the two locomotions. The results from this study support this finding as overall subjects were able to come very close to reaching their forward HR max during their backward max tests. Precisely, participants were able to reach 94-99% of their forward HR max during the backwards max tests with a significant increase in this percentage from pre to post tests which is believed once again to be a result of familiarization to the backwards max protocol. A trend of increased relative V02 max from pre to post backward max test can be observed in the BG. In addition to this observation and in coincidence with previous studies, subjects reported quadriceps fatigue and difficulty in maintaining BR at higher inclines more detrimental to their performance during the backward max tests than general fatigue or breathlessness (Flynn et al., 1994). Therefore, with the practice and familiarization to backwards running the BG was exposed to, it is assumed that this group showed a trend to increase in backwards V02 max due to being able to last longer in the backwards max test and thus being able to achieve an increase in post V02 max. More specifically, it is believed that the training program may have prolonged the local quadriceps fatigue reported previously by increasing quadriceps or knee extensors strength as previous studies have suggested (Flynn & Soutas-Little, 1993; Threlkeld et al., 1989). Furthermore, the idea of the observed trend being a result of the ability to last longer in the backwards max test is supported by the significant results that were found between the NBG and BG. Overall, the BG made more of a significant increase in the minutes they lasted in the backwards max test from pre to post tests. Although, the current study lacked a FR group it is believed that this trend is not a result of aerobic training as this trend was seen only in the backwards max test data. However, the formerly mentioned observation was also a surprising result as typically it would be expected to see effects on forward V02 max with aerobic training in general. It is speculated that no
effects were found possibly due to non-reported decreases in BG subjects’ former aerobic training regimens due to addition of the backwards running program. Moreover, BG subjects’ oxygen consumptions were not monitored during training sessions and therefore they may have not been training at a high enough percent of V02 max to elicit such changes. Next, another trend that can be observed was a decrease in lactate in all subjects from pre to post backward max tests suggesting possibly heightened mechanical efficiency of the involved motor pathways due to the pre test exposure. This would then allow for less motor unit recruitment during BR and thus lower lactate production by the involved muscles. Prior investigations observed that lactate levels during backward max testing did not reach those levels seen during forward max testing (Flynn et al., 1994). This can be observed in the current study as well and is believed to be a result of not being able to achieve forward V02 max levels during backward max tests likely as a result of the mechanical difficulty. This idea is reinforced as it was seen that all subjects could only achieve 77-84% of their relative forward V02 max during both their pre and post backwards max tests. In addition, another study similarly reported all relative V02 maxes were greater during forward max tests (Flynn et al., 1994). However, the current study also demonstrates a trend for an increase in this percentage with BR training suggesting that with a longer term training program, achieving forward V02 max levels during a backward max test may be possible despite other difficulties.

The second objective of this study was to examine the effects of a BR program on equilibrium. Previous literature has suggested that BM would have a beneficial effect on balance. Contrary to these implications, very few significant changes in balance or equilibrium were found. It was seen that regardless of the treatment condition, all participants showed a significant increase in postural sway pre to post tests, suggesting a decrease in balance, along the M-L axis when standing in the left leg only position. Additionally, it was reported that those in the NBG tended to spend more time swaying farther away from their COP in the M-L axis while on the right leg only despite the time they were tested. It is believed the previously mentioned results may have been a result of leg dominance which was uncontrolled for in this study. Despite the lack of statistically significant results yielded, once again the observable trends should be distinguished. In general, the BG seemed to have a tendency to have an increase in balance along the M-L axis or stay about the same from pre to post tests while the NBG had a tendency to have a decrease in M-L balance. Additionally, the BG appeared to have a reduction from pre to post
tests in time spent swaying farther away from their COP along the A-P axis in the single leg stance conditions; while the NBG seemed to increase from pre to post tests in time spent swaying farther away from their COP along the A-P axis in the same conditions or again show a decrease in equilibrium. These trends regarding the increasing equilibrium in the BG may be explained by the motion involved in BR. It has been noted that during BR, the muscles active at toe stance include vastus lateralis, vastus medialis oblique, rectus femoris, and the lateral head of the gastrocnemius. Furthermore, later on in initial stance during BR, biceps femoris and tibialis anterior are also activated. While in FR, all the above muscles are activated during initial stance with the exception of biceps femoris. Even more, there is an increase duty cycle of all these muscles during BR compared to FR (Flynn & Soutas-Little, 1993). Therefore, it can be speculated that the increased activation of the above muscles during BR may lead to increased gains in muscular strength. More particularly, biceps femoris as a major muscle of the hamstrings group seems to be more active during BR than FR possibly allowing for an often lacking muscular balance to occur between the quadriceps and hamstrings with repeated bouts of BR (Flynn & Soutas-Little, 1993). This would correspond to an increase in equilibrium most likely along the A-P axis as demonstrated with our most promising trends of decreasing sway in the one legged conditions in the BG along this axis. Another possible explanation to these trends adding to the idea of increased muscular balance may be found in the leaning position post FW and BW bouts. De Nunzio et al. (2008) reported that post BW and FW subjects showed backward and forward leaning respectively during quiet stance. Even more, these characteristics lasted up until ten minutes post trial. The authors speculated the backward leaning observed following BW was due to less flexion of the trunk during BW causing a more rearward placed orientation post trial. It is therefore hypothesized that repeated bouts of BM would then cause a more longer term effect on the involved trunk and leg muscles once again allowing for an antagonist/agonist muscular balance to occur which might be seen again most likely in the A-P axis as our trends suggest. It should be noted that equilibrium commonly includes other components such as vision and hearing and more over despite support BM has also been speculated to heightened these components as well, however the current study only focused on more muscular components of balance.

Lastly, this experiment attempted to quantify the adaptation period to BR as measured by decreases in physiologic novelty of task. A previous analysis by Childs et al. (2002), found that
it took between 12 to 18, 20 minute BW sessions at 60 % of V02 max before the novelty of the BM began to decrease. This study reassessed subjects every two weeks to adjust speed to meet intensity guidelines and relied on self-report. Chaloupka et al. (1997) recommended that due to the novelty of BW there was an important need to continually monitor the training response to BW so that as novelty decreased, the individual could make adjustments to ensure proper intensity to maintain aerobic fitness. Moreover, it was stated that individuals exhibit 15% less mechanical efficiency during BR than FR but that however this may be reduced with training (Cavagna et al., 2011). Therefore, this research aimed to more accurately quantify this adaptation period by re-assessing participants every day over a period of three weeks. In general, it was observed that almost all subjects had to have the treadmill speed increased during the three week treatment period in order to elicit the same vigorous intensity as measured by percent of heart rate max. More specifically, it seems there was a decrease in average daily heart rate from day seven to day eight; and thus a corresponding trend to increase in speed on day nine to elicit the appropriate heart rate was present. Therefore, in contrast to Childs’ et al. (2002) findings, we propose that the novelty of BM may begin to decrease in as short a time period as one week or within seven to 15, 20 minute sessions of BM. Additionally, previously an equation for prescribing BW speeds to elicit certain HRs and V02s was presented by Myatt et al. (1995), from this study and others it is believed that this equation should only be used for the those with no previous exposure to BM; as it is evident that once novelty decreases this equation may no longer be of relevance. Lastly, as stated before, most prior research regarding BM has incorporated a familiarization session to BM before data was collected. One particular study reported that there was a lower joint position curves during BR for both a runner experienced with BR and a naïve subject who participated in a BR practice session compared to the others who had no experience with BR (Devita & Stribling, 1991). This suggests that just one familiarization session with BR could already have effects on novelty. The current study also supported this idea as all subjects including the NBG who only had the pre test exposure showed a significant increase from pre to post tests in time lasted in backwards max tests. This may indicate that after just one session, efficiency of motor unit recruitment or motor pathways may already start to increase which would perhaps then decrease the difficulty of the task and allow for the longer backward max tests times as was seen in the current research. However, the NBG did not present the trend to increase in backwards V02 max as the BG did suggesting the one
session may have not been enough exposure to significantly overcome the physiologic novelty of task component of BR but rather only begin to more fully develop the motor pathways involved.

In light of the trends and results seen, there were several major limitations to the current study. First and foremost, the sample size obtained was extremely small and greatly impacted the ability to obtain statistical significance. This small sample size also lent to a high impact or skewing of results by outliers such as most prominently the more anaerobically fit and aerobically unfit subject’s results in the BG. Even more, the lack of subjects makes it difficult to generalize any results from this research. Next, this study lacked a FR group and so we are unable to accurately attribute any trends directly to the BR program. Thirdly, Threlkeld et al. (1989) showed that the kinematics of BR on a treadmill seemed to require different motor strategies from those of free BR, suggesting that treadmill running in general could have impacted most predominantly the equilibrium results of this study. Lastly, the reliability of the HR monitors and lactate meters was of question and may have lent to decreases in accuracy.

Future studies involving BR should investigate other components of equilibrium such as hearing and vision changes. In addition, further investigation should include a larger sample, different age groups, both treadmill BR and free BR, and more diverse fitness levels. Finally, there are implications for a longer term study.

**Conclusion**

This study demonstrated promising possibilities for increases in cardiorespiratory and metabolic variables and balance with a BR program. Furthermore, the research suggested novelty of BR decreases in as little as one week or seven to fifteen, 20 minute sessions. Overall, the BG running group rated the difficulty of the program as somewhat easy to somewhat difficult. One subject suggested the program could be improved by including increases in inclines and more speed increases while the rest were satisfied with the program as it was. Additionally, all subjects in the NBG said they would not incorporate BR into their workout routine while 50% of the BG said they would incorporate BR into their workout. Results from this study may be implicated for use in developing and prescribing BR programs for those wanting to increase or maintain aerobic fitness and balance while allowing for adjustments to be made continually as novelty decreases. Lastly, this information may be used when developing future studies targeting the variables examined more in depth.
Reference List


APPENDIX

Appendix A: Health History Questionnaire

HUMAN PERFORMANCE LABORATORY

MIAMI UNIVERSITY

MEDICAL HISTORY QUESTIONNAIRE

ID# ______________________

SCHOOL ADDRESS ____________________________________________________________

PERMANENT ADDRESS __________________________________________________________

DATE OF BIRTH _____ / _____ / _______ Age ________

PHONE NUMBER _______________________________________________________________

E-MAIL ADDRESS ______________________________________________________________

HAVE YOU EVER HAD OR BEEN DIAGNOSED WITH ANY OF THE FOLLOWING?

Heart Attack YES NO

Coronary Surgery YES NO
Chest Discomfort  YES  NO
High blood pressure  YES  NO
Shortness of breath on light exertion  YES  NO
Pulmonary disease  YES  NO
Heart palpitation  YES  NO
Heart murmur  YES  NO
Diabetes  YES  NO
Dizziness on light exertion  YES  NO
Extremity Discomfort  YES  NO
Swelling of lower extremities  YES  NO

DO YOU HAVE A FAMILY HISTORY OF CARDIOVASCULAR DISEASE?  YES  NO

IF YES, WHO?___________________________________________________________
DO YOU CURRENTLY SMOKE?  YES  NO

ARE YOU CURRENTLY TAKING ANY PRESCRIPTION MEDICATIONS?  YES  NO

IF YES, WHAT (Please List)?________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

ARE YOU CURRENTLY TAKING ANY OVER-THE-COUNTER MEDICATIONS?  YES  NO

IF YES, WHAT (Please List)?___________________________________________________

____________________________________________________________________________

ARE YOU ALLERGIC TO ANYTHING?  YES  NO

IF YES, WHAT? _________________________________________________________________

WHAT IS YOUR CURRENT TOTAL CHOLESTEROL LEVEL (IF KNOWN)?  ________________

ESTIMATE YOUR CURRENT PHYSICAL ACTIVITY LEVEL:  LOW  MODERATE  HIGH
Appendix B: Exercise participation questionnaire

Exercise Participation Questionnaire

All information on this form will be kept confidential. Please fill out this questionnaire completely and accurately.

Study ID: _______________________

1) Have you been exercising consistently (on average 3 or more times per week) for the past 3 months?

   YES       NO      (Please Circle One)

3) How often do you take part in physical exercise? (Please Circle One)

   5-7x/ week  3-4x/ week  1-2x/ week  1x/ week at most

4) How long do you exercise per session? (Please Circle One)

   <15 min/session  15-30 min/session  30-60 min/session  >60 min/session

5) Are you able to run at least 15 minutes continuously? (Please Circle One)

   YES       NO

6) What is the intensity level of a typical exercise session? (Please Circle One)

   Low Intensity  Moderate Intensity  Vigorous Intensity

7) When exercising do you participate in mostly aerobic (example – jogging / running, cardio workouts, etc.) or anaerobic (sprinting, weight lifting, strength training, etc.) physical activities?

   Aerobic       Anaerobic
Appendix C: Consent form

Consent Form
The Effects of a Short-term Backward Running Program on Aerobic Capacity, Equilibrium, and Physiologic Novelty of Task

The purpose of this study is to investigate the effects of a 3 week backwards running program on cardiorespiratory fitness variables and balance. Previous work has found increased cardiovascular, metabolic, and balance benefits resulting from backwards locomotion as compared to forwards locomotion. Researchers can use this data to conduct further research into prescribing special and healthy populations such a program for those improvements in cardiorespiratory fitness and balance we may find. Additionally, this information may be used in further research to develop a long-term backwards locomotion program for those where forward locomotion has been contraindicated or hindered due to injury or disease and in which improving and maintaining cardiorespiratory fitness and balance is an objective. The entire study will take approximately 5 weeks. Each pre and post program testing sessions will take approximately 1 hour and you will complete the below described tests a total of 2 times over the entire study duration.

At Phillips Hall, balance tests will provide initial data as to your level of balance prior to the start of the running program. You will be asked to stand on one-leg (and both legs), eyes closed (and open), and arms crossed over your chest for 30 seconds each. Also in Phillips Hall, two maximal exercise tests, one forwards and one backwards, will determine your aerobic fitness level. During the exercise tests you will be tested for presence of increasing amounts of lactate in the blood utilizing a lactate analyzing device. Before each exercise test and immediately after each test, a gloved investigator will obtain the blood bolus via a finger prick with a safety lancet. In addition while performing the exercise test you may experience muscle fatigue and breathlessness. There is the slight chance of an abnormal blood pressure response, a heart attack, or death during the graded exercise test. After the exercise session you may also experience slight muscle soreness. Published data support the risk of an abnormal cardiovascular event as very low, especially in normally active individuals and athletes. All testing will be conducted in accordance to standard procedures and published guidelines established by the American College of Sports Medicine. Should any injury result from participation in this study we will provide standard emergency medical care in accordance with guidelines established by the Department of Kinesiology and Health. If costs are incurred as a result of medical attention, the costs will be your responsibility.

Upon completion of the pre-tests, you will be randomly assigned to the no treatment or backward running group for the 3 week intervention period. The backwards running program will require you to run for a total of 20 minutes (broken up into two ten minute bouts), for 5 days a week (for the 3 week duration) on the treadmills located in Phillips Hall while supervised by a primary
investigator. You will be required to wear a heart rate monitor while running so data may be collected. The no treatment group will simply not do any backwards training during the intervention period. Upon completion of the program, both groups will undergo the same tests used before the start of the intervention period. Benefits from your participation in this study may include improvements in cardiorespiratory fitness and balance and thus decrease risk of cardiovascular disease and injuries resulting from poor balance.

While we are working to possibly provide monetary compensation upon completion of the study through funding, at this time it should be assumed that your participation in this project is completely voluntary and is greatly appreciated. In addition, you are permitted to withdraw from the project at any time throughout the research project either in person or by emailing a primary investigator. Upon withdrawal, all data collected will be destroyed. All identifying information will be kept confidential through a number code system. Only the student investigator(s) and faculty advisor will have access to your name and identifying information.

Please feel free to contact Michelle J Pesek, the study director at pesekmj@muohio.edu or Dr. Mark Walsh, the study advisor at 529-2708 for any questions or concerns you may have. The Office of the Advancement of Research and Scholarship 529-3600 can be contacted if you have any questions concerning your rights as a subject.

The person signing below must be 18 years of age minimally. If you agree to participate in this research project, please sign the slip at the bottom of this page. If you choose to withdraw from the study, you will still be entitled to all services normally offered through the Departments of Kinesiology and Health.
Appendix D: Post participation questionnaire

Post Participation Questionnaire

All information on this form will be kept confidential. Please fill out this questionnaire completely and accurately. Intervention group please fill out all questions, No-Intervention group only answer question two.

Study ID: _______________

1) Rate the overall difficulty level of the backwards running program. (Please circle one)

   Very Difficult  Somewhat Difficult  Neutral  Somewhat Easy  Very Easy

2) Do you believe you will incorporate backwards running into your workout routine in the future?
   (Please circle one)

   YES  NO

3) Is there anything you would have changed about the backwards running program? If yes, please say what. If no, leave blank.
Appendix E: Borg Scale

Borg Rating of Perceived Exertion Scale

6  No exertion at all

7  Extremely light

8  

9  Very light

10 

11  Light

12 

13  Somewhat hard

14 

15  Hard (Heavy)

16 

17  Very hard

18 

19  Extremely Hard

20  Maximal Exertion
Appendix F: Infectious Waste Management Guidelines

Laboratory Procedures for Medical Emergencies/Injuries

Department of Kinesiology and Health

A. Life threatening situation (e.g., cardiac arrest).

1. In a life threatening situation, call 911* from the nearest phone, and initiate lifesaving measures such as CPR, defibrillation, etc. The Automated External Defibrillator (AED) is located in Room 106 Phillips Hall. First aid kits are located in Rooms 17, 23, and 29/36 (see map below).

2. Do not move person unless there is danger of further harm.

3. Remain with person until emergency personnel arrive.


B. Serious - but non-life threatening situation (e.g., fracture).

1. In a serious, but non-life threatening situation, call 911* (if necessary) from the nearest phone, and initiate first aid measures. First aid kits are located in Rooms 17, 23, and 29/36.

2. Do not move person unless there is danger of further harm.

3. Remain with person until emergency personnel arrive, or until the emergency is otherwise resolved.


C. Minor injury/medical event.

In the case of a minor injury/medical event, initiate first aid measures immediately. First aid kits are located in Rooms 17, 23, and 29/36. Complete KNH accident report form.

*When calling 911 be prepared to provide as much of the following information as possible:

- Your name and exact location.
- Description of injury or illness.
- Condition of the victim(s) (conscious, breathing, bleeding, chest pain, etc).
- Approximate age of the victim(s).
- Exact location of the victim(s).
- Do not hang up until the dispatcher instructs you to do so.
Note: Personal protection during the administration of first aid is critical. You must adhere to “Universal Precautions” when responding to emergencies which provide potential exposure to blood and other potentially infectious materials. “Universal Precautions” stresses that all persons should be assumed to be infectious for HIV, Hepatitis viruses, and other blood borne pathogens.

Persons responding to a medical emergency should be protected from exposure to blood and other potentially infectious materials. Protection can be achieved through adherence to work practices designed to minimize or eliminate exposure, and through the use of personal protective equipment (i.e., gloves, masks, and protective clothing), which provide a barrier between the worker and the exposure source. For most situations in which first aid is given, the following guidelines should be observed.

- For bleeding control with minimal bleeding and for handling and cleaning instruments with microbial contamination, disposable gloves should be worn. Disposable gloves are located in Rooms 17, 23, and 29/36.

- For bleeding control with spurting blood, disposable gloves, a gown, a mask, and protective eye wear should be worn. Disposable gloves, gowns, masks, and protective eye wear are located in Rooms 17, 23, and 29/36.

After emergency care has been administered, hands and other skin surfaces should be washed immediately and thoroughly with warm water and soap or a disinfectant agent if contaminated with blood, other body fluids to which universal precautions apply, or potentially contaminated articles. Hands should always be washed after gloves are removed, even if the gloves appear to be intact. All contaminated work surfaces should be washed immediately and thoroughly with warm water and soap or a disinfectant agent. All contaminated materials (gloves, etc.) should be disposed of in the appropriate biohazard waste containers located in Rooms 17, 23, and 29/36, following these Miami University Infectious Waste Management Guidelines.

1. SEGREGATE infectious waste from non-infectious waste at the point of generation.

2. PLACE infectious waste in red bags or plastic bags labeled with the international biohazard symbol. These bags are located in Rooms 17, 23, and 29/36. SHARP infectious wastes must be placed in containers specifically designed and manufactured for the management of SHARPS. These containers must be labeled with the word SHARPS as well as the international biohazard symbol. SHARPS containers are located in Rooms 17, 23, and 29/36.

3. TRANSFER all infectious wastes to an approved storage location (Miami Student Health Service) for all subsequent off-site treatment and disposal.