CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

It has been established that the recently introduced inclined stepper (SM) is an appropriate tool for measuring VO_{2peak} on individuals when testing on a treadmill (TM) is neither accessible or desirable (Davis and Sipe, in press). However, limitations during constant-load exercise on the SM have yet to be examined. One of the possible limitations is an "excess" consumption of oxygen (slow component) over that predicted for submaximal exercise. The slow component (SC) of VO_2 can rise to levels close to that of peak thereby compromising performance by eliciting premature fatigue. The exact mechanisms influencing SC have not been identified, however, the importance of evaluating SC during constant-load exercise has been established.

For this study, twenty-two college aged (18-30) males (n=11) and females (n=11) gave their informed consent upon admittance into the investigation. Subjects completed a total of four exercise bouts. Subjects performed one maximal exercise test on the TM and SM to establish a workload for submaximal exercise. Prior to establishing the design of the study, it was determined from a previous investigation by Davis and Sipe (in press) that the incremental stepper had a high test-retest reliability (r=0.91). High reliability of peak oxygen uptake has also been found during repeated incremental TM tests. Gardner et al. (1995) reported a reliability coefficient of r=0.87 during TM testing. Therefore, the investigator conducted only one incremental test on the SM and TM to obtain peak VO_2 values. Approximately 48 hours after maximal testing on each apparatus, subjects performed a 20-minute submaximal exercise bout at a workload equal to 70% of peak oxygen uptake.

The primary response variables investigated in this study were the VO_2 slow component (SC), heart rate (HR), and lactate [HLa]. For the constant-load exercise bouts, response variables were assessed at rest and 5, 10 ,15, and 20-minutes of exercise to evaluate the rate of change between the two modes.

Results

Determination of maximal exercise included two of the following three criteria: HR$\geq$85% age predicted maximum, RER$\geq$1.10, and RPE$\geq$17. All subjects met criteria for maximal exercise (see Table 4). Compared to the stepper, the treadmill showed higher responses during maximal exercise for VO_2 (3847$\pm$164, 2747$\pm$587 ml/min), HR (194.0$\pm$8.1, 180.7$\pm$9.7 bpm), and [HLa] (10.2$\pm$2.5, 8.9$\pm$2.2 mMol/L). In contrast, maximal exercise elicited higher RER values for the stepper compared to the treadmill (1.22$\pm$.04, 1.12$\pm$.07).

Between minutes 5 and 20 of exercise on the SM, VO_2 increased 116.5 ml/min compared to 59.0 ml/min on the TM. HR increased across exercise 13.0 bpm for the SM while HR on the TM increased 10.0 bpm. Similar increases in lactate were evident over the same time period. Between minutes 5 and 20, the SM had an average increase of 1.40 mMol/L compared to 0.78 mMol/L for the TM. It was interesting to note that from minutes 5 to 20 lactate concentrations actually decreased slightly (4.89-4.83 mMol/L) for TM exercise. A two-way ANOVA with repeated measures was performed to determine if the rate of change for VO_2 , HR, and [HLa] was significantly different for the SM vs TM exercise. No differences between the two modalities were found for any of the response variables ($P>0.05$).

The simple main effects test revealed within condition changes across the four collection periods for VO_2, HR, and [HLa] (see Table 3). The constant-load SM exercise revealed changes in VO_2 from minutes 5 to 10, 5 to 15, and 5 to 20. No differences for VO_2 across time were found for the TM. Unlike the VO_2 response, within condition changes in HR were found for both modalities of exercise. For the SM, changes were seen from minutes 5 to 10, 5 to 15, 5 to 20, and 10 to 20. The TM revealed changes in HR from minutes 5 to 10, 5 to 15, and 5 to 20. Blood lactate concentrations were also evaluated and showed within condition changes for both the SM and TM. From minutes 5 to 10, 5 to 15, and 5 to 20, there was a change in [HLa] for the SM. Changes in [HLa] were evident from minutes 5 to 15, and 5 to 20 for the TM. All changes for simple main effects were significant at $P<0.05$.

Discussion

The purpose of this study was to compare the changes in VO_2 (SC), HR, and [HLa] during 20-minutes of constant-load exercise on an inclined stepper (SM) and treadmill (TM). The baseline maximal incremental exercise tests revealed higher values for VO_{2peak} (21.2%), HR (5.6%), and blood lactate (12.7%) for the TM compared to the SM. While this is the first study to examine blood lactate responses on the SM, similar results for VO_2 and HR were found using identical exercise equipment in the study by Davis and Sipe (in press). For that study, the TM elicited higher VO_{2peak} (15.6%) and HR (5.2%) values for college-aged (18-30 yrs) subjects. Although the present study supports the results from Davis and Sipe, it does not support the results from studies using different variations of stair climbing equipment. Holland, Hoffman, Vincent, Mayers, and Caston (1990) evaluated VO_2 and HR during maximal exercise on a treadmill and a stair climber that utilized revolving steps in its design. Results from that study showed identical VO_2 and HR responses between the modalities. Because the mechanics of stepping on machines with revolving steps are different than the SM, direct comparison between the results of the present study and Holland and colleagues may not be appropriate. Reasons for the different responses between the two studies is not fully understood, but it could be hypothesized that body position may have been a factor. During stair climbing exercise, the body is in an upright position similar to treadmill exercise. Compared to exercise in a supine or inclined position such as on the SM, an upright position results in a smaller venous return of blood to the heart thereby increasing cardiovascular demand. As a result, physiological responses may be elevated on the TM and traditional stair climber.

Furthermore, the use of the upper body may account for differences in VO_2 and HR between the SM and other stair climbers. Treadmill and stair climbing use the arms for either balance or support during exercise. On the SM, the upper body is being supported by the inclined positioning of the back therefore the arms are not being used. As a result, less muscle mass is involved in exercise, thereby decreasing cardiovascular demand.

The RER values from maximal exercise contrast the results found for VO_2. Typically, the greater the VO_2, the greater the RER. However, the SM elicited an RER response of 8.2% (1.22 vs 1.12) higher than the TM. The exact reason of the elevated RER values on the SM is not known, but localized fatigue in the lower extremities may have caused a hyper-ventilatory response thus increasing the amount of CO_2 production..

The main variable assessed in this study was VO_2SC. Although not significant, the increase in VO_2 from minutes 5 to 20 of constant-load exercise was greater for the SM (116.5 ml/min) compared to the TM (59.0 ml/min). Constant-load exercise on the SM at 70% of peak oxygen uptake resulted in an extra 02 consumption of 57.5 ml/min compared to the TM. According to Gaesser and Poole (1996), it is not uncommon to observe a SC range of 500 ml/min to 1000 ml/min during heavy (i.e. above LT) constant-load exercise. A SC with the magnitude suggested by Gaesser and Poole would compromise performance and eventually result in early-onset fatigue. The magnitude of SC found in the present study does not correspond to the magnitude found in previous studies. Exact reasons for the differences are not known, but it could be hypothesized that the uniqueness of the SM does not place a greater demand on VO_2 than has been demonstrated by the TM. This finding would be important for individuals working in a fitness related field. Exercise physiologist would be able to prescribe exercise knowing that SC would not limit a typical session.

A two-way ANOVA with repeated measures revealed no differences between the two modalities for VO_2, HR, and [HLa] during constant-load exercise ($P>0.05$). The main finding of this study was that the rate of change in VO_2 over the 20-minutes of exercise was not significantly greater than the TM ($P=.096$). One factor that was not identified for this study was the lactate threshold. In order for SC to become evident during exercise, individuals must be working above their lactate threshold (Gaesser & Poole, 1996). Past literature has defined the lactate threshold as a lactate concentration above 4 mMol/L during constant-load exercise. For this study, lactate concentrations were above 4 mMol/L for each collection period. However, it should not be assumed that every subject was exercising above their LT. Recently, it has been shown that LT is specific to the individual and that the 4 mMol/L level chosen to define LT is obscure. It may also be pointed out though that the workload selected for this study has been shown to be adequate in pushing exercise above the LT (Hagberg, Mullin, & Nagle). Exercise at an intensity equal to 50 to 60% of VO_{2max} usually elicits a rise in blood lactate only in relatively unfit individuals. As the exercise intensity increases, there is an exponential rise in blood lactate concentration (Gollnick, Bayly, & Hodgson, 1986). Therefore, the 70% VO_{2peak} workload chosen for this study would seem to be sufficient in evoking blood concentrations above the LT.

The results of this study also point out that HR and [HLa] values were not significantly different between the two modalities. These findings were not unexpected since no difference was found for VO_2. Had there been a difference in the rate of change for VO_2, then a concomitant change in HR and [HLa] were hypothesized. The decrease in lactate concentration from minutes 15 to 20 on the TM is not an unusual response during constant-load exercise. For work intensities above the LT, [HLa] increases during the first 10-15 minutes of exercise attaining a constant-value, or decreasing slightly, as the exercise is prolonged (Antonutto & Prampero, 1995).

The simple main effects test revealed an interesting finding for VO_2 during the 20-minutes of exercise. Changes in VO_2 were evident along 3 collection periods for exercise on the SM while the TM showed no changes. This finding is a little unusual since the rate of change between the two modalities was not significant. It could be hypothesized that the change in VO_2 on the SM from minutes 5 to 10, 5 to 15 and 5 to 20 was due to the lowered relative VO_2 response. At minute 5 of exercise the SM had a 20.9% lower VO_2 than the TM. Similarly , minutes 10 (19.9%) 15 (18.8%) and 20 (18.3%) of exercise were lower for VO_2 on the SM. These lowered responses were to be expected since VO_{2peak} on the SM was 21.2% less on the SM compared to the TM. Therefore, the observed changes in VO_2 on the SM may be a result of the relatively smaller VO_2 response compared to the TM.

Recommendations for Future Research

The gereralizability of this study is somewhat limited. The results of this study apply only to males and females between the ages of 18 and 30. The inclined stepper has become more and more popular with rehabilitation centers in recent years. Therefore, primary focus for continued research on this device should be with older populations, especially those with cardiovasclar disease. Results from a study using a traditional stair climber showed that claudication patients may benefit from this activity because of a reduced cardiovascular demand during stair climbing compared to treadmill walking (Gardner et al., 1995). If the same is true for the inclined stepper, than this piece of equipment would be of great benefit to those who frequently have concomitant cardiovascular problems during exercise, such as hypertension, and myocardial ischemia.

Another factor that needs to be assessed is the role of the exercising limbs in the response to exercise on the SM. Previous literature has shown that the majority of the VO_2 slow component exists from within the exercising limbs (Poole et al., 1994). Since the SM primarily utilizes the lower extremities, it would be advantageous to know the extent to which the legs contribute to exercise on this machine. Exercise on an inclined stepper may be considerably easier for those with larger lower extremities. Exercise physiologists may need to take leg mass into account when prescribing exercise on the device.

Future research in the realm of fitness and training using the SM needs to be addressed. For the serious runner who wants to sustain interest and reduce the potential for injury, direct comparisons for aerobic capacity need to be made between training on a TM and SM. If results are similar, the SM may prove to be a viable cross-training alternative to the persistent stressors that running places on the lower extremities.

Finally, the inclined stepper has been advertised to improve or build lower extremity strength. Knowing the extent to which the exercise helps in building strength in older populations would be useful. If the SM can produce significant gains in lower extremity strength, then the elderly population may benefit considerably. Such gains in strength may increase balance thus lowering the risk of bone fractures due to falls. Decreased prevalence of fractures may lead to increased independence of living. This is one advantage that other cardiovascular equipment may not offer.

Summary

This study compared the physiological and metabolic cost of constant-load exercise response of the inclined stepper (SM) with the traditional treadmill. SM exercise resulted in lower VO_2, and HR values during maximal exercise which was not uncommon. No significant differences for changes in VO_2, HR, and [HLa] between the two modes were found during constant-load exercise. The major finding of this study was that the SM did not produce a significantly greater VO_2SC than the treadmill during constant-load exercise. Based on these findings, the inclined stepper appears to be an appropriate exercise modality and may offer advantages over traditional exercise equipment. Beside the low-impact nature of the SM, it also improves lower body strength. Now that the inclined stepper has been tested under typical exercise conditions, individuals working in a fitness setting may prescribe exercise on this device with confidence knowing that it is an effective piece of exercise equipment.

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