A Comparison of the Physiological Response and Pain Perception Between Two Mechanically Differentiated Cross Trainers

An independent research study conducted by the University of North Carolina at Charlotte compared the perceived effort and metabolic effects between the Cybex Arc Trainer and a popular elliptical trainer. The principle difference between these two devices is the movement pattern of the footplates. The footplate of the ARC trainer moves along an arcuate path, while remaining level to the ground throughout the motion cycle. The elliptical trainer footplate moves along an ellipse, while the footplate tilts forward at different points during the movement cycle.

Biomechanical analyses of these patterns have revealed differences in the force trajectories created during exercise on these devices, with significant differences in torque loading at the knees, hips, and back. The purpose of this study, therefore, was to determine if subjects using these devices would detect differences in perceived exertion and joint discomfort, and to see whether the mechanical loading differences between the machines would result in disparate heart rate and metabolic responses to exercise.

Methods

Eighteen subjects (10 male, 8 female) volunteered for this study. Mean age was 24.7 ± 2.6 years, body mass was 69.8 ± 14.9 kg, height was 172.2 ± 10.3 cm, and body fat was 22.5 ± 8.1 %.

Maximal oxygen consumption was first established on the two devices. Subjects then exercised at steady state levels of 55%, 65%, and 75% of their VO_2max on each device. At each level, heart rate data were collected, and subjects reported on overall perceived exertion as well as indicators of perceived discomfort at the low back, hip, and knee.

Results

VO_2max values of 51.2 ± 12.1 for the Arc and 50.2 ± 11.1 for the elliptical were not significantly different. Heart rate responses on the Arc, however, were significantly lower at the three predetermined levels of VO_2max. When data were normalized for heart rate, subjects consumed more oxygen on the Arc than on the elliptical. These data are displayed in figure 1.

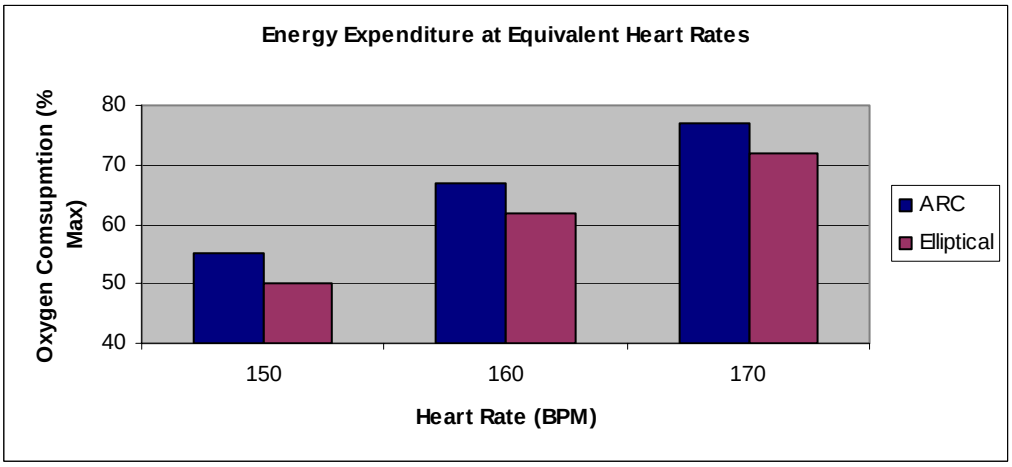

Figure 1. Energy Expenditure at 150, 160, and 170 BPM

Since caloric expenditure is a direct correlate of oxygen consumption, total calories burned can be determined for an individual exercising on these devices for a period of time. In figure 2, we can see the caloric expenditure after thirty minutes of steady rate exercise, for one subject weighing 68.2 Kg, with a VO_2max of 50 ml/kg/min.

It is evident from the data that subjects exercising at a steady heart rate, for a thirty minute interval, will burn more calories on the Arc than they will on the elliptical trainer.

Thus, in order to achieve comparable results on the elliptical trainer, subjects will have to work longer, or work harder, than they would on the Arc trainer. As we will see in the data to follow, this is very difficult to accomplish.

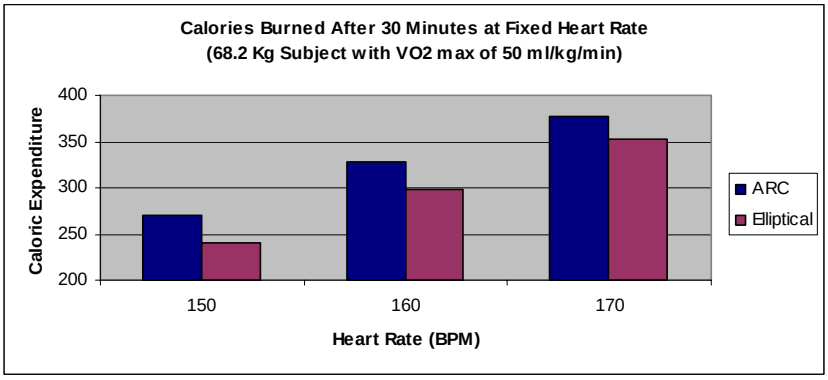

Figure 2. Caloric Expenditure on the Arc and Elliptical Trainers

Whole-body ratings of perceived exertion were collected at the three exercise intensities. The results indicated that perceived effort increased as a consequence of increasing exercise intensity on both exercise devices. On the other hand, overall perceived exertion scores were significantly lower on the Arc than they were on the elliptical at similar work intensities ($p < .01$). Thus, subjects reported that they were working harder on the elliptical, even though their level of metabolic effort was identical on both machines.

Additionally, subjects were asked to report on the level of discomfort that they felt in their low back, hips, and knees at all three exercise intensities. At a relatively low intensity (55% VO_2max), perceived discomfort scores were similar. But when exercise intensity was increased to 65% VO_2max, a level more indicative of typical exercise workloads, those scores changed dramatically.

Figure 3 displays the perceived discomfort ratings for the knee, hip, and low back on the Arc and elliptical trainer, at 65% of subjects' VO_2max.

It is clearly evident from these data that subjects felt significantly more discomfort in key body regions while exercising on the elliptical trainer, even at moderate workloads.

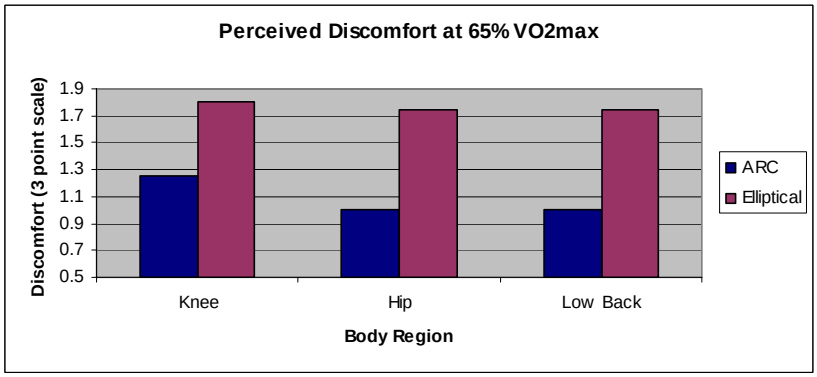

Figure 3. Perceived Discomfort at 65% VO_2max

Perhaps, even more interesting, was the subjects' sense of discomfort as workloads were increased. One might anticipate that as exercise intensity increased, the perception of discomfort would also increase concomitantly. Not surprisingly, this occurred when subjects exercised on the elliptical trainer. As seen in figure 4, reported discomfort levels increased steadily from 55% to 75% VO_2max. Thus, the harder subjects worked, the more uncomfortable the exercise became.

Interestingly, this pattern was not replicated on the Arc. As depicted in the figure, the reported levels of discomfort did not increase at all with elevated workloads. In other words, regardless of how hard subjects worked on the Arc, the stress imparted on them by the machine remained relatively low.

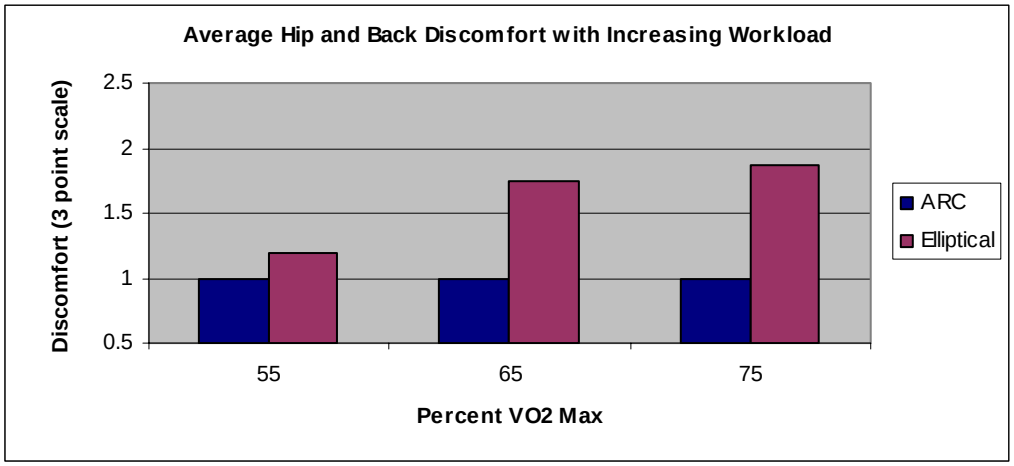

Figure 4. Average Perceived Hip and Back Discomfort with Increasing Workload

Discussion

The results that one can achieve on any piece of equipment are largely dependent upon the workload that one establishes during exercise. The harder one works, the more oxygen they'll consume, and therefore, the more calories they'll burn.

In this study it was demonstrated that subjects exercised with significantly lower perceived exertion and body discomfort on the Arc, as compared to a popular elliptical trainer, even when at the same level of metabolic exertion. Thus, if they set their workload according to their perceived effort then they would naturally work harder and burn more calories on the Arc.

It was also shown that the heart rate response to prescribed levels of exercise was lower on the Arc. Thus, just as with perceived effort, if subjects adjusted their workloads on the different exercise devices to evoke a constant heart rate, they would also consume more oxygen and burn more calories on the Arc.

The differences in the perception of effort and the metabolic responses to exercise on these devices can largely be explained by the mechanical loading imparted by them. As discovered by Graves and Juris (2005) and later corroborated by Lu et al (2007), elliptical trainers create lines of force resulting in high levels of stress on the knees and back, with little work performed by the large hip extensor musculature.

By contrast, the Arc produces lines of force resulting in balanced torque loading between the hip and knee, with less stress imposed on the joints and low back. Since the larger muscles around the hip are more fully engaged during exercise on the Arc, there is also a greater consumption of oxygen and caloric burn, even at lower heart rates.

References

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