INTERSEGMENTAL COORDINATION IN STAIR CLIMBING

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Stair climbing has become a popular form of training for athletes as well as non-athletes. Considering that there are a plethora of devices for stair climbing. how does a person decide which apparatus to use? Aside from issues of practicality, much of the decision could be based on the principles of specificity of training. That is, for maximum transfer of benefits from one activity to another, the activities should be compatiile in the usage of energy systems, muscle groups, and patterns of coordination. As for the first two criteria of specificity, the choice is simple: almost all stair climbing devices are beneficial to the aerobic energy system and the leg extensor muscles. However. for the criterion of coordination, the choice may be more difficult. First, the reasons for exercising on stairs are diverse. They can range from cross-training for the serious athlete who wishes to gain a competitive advantage to reconditioning for the injured or elderly person who wishes to safely negotiate the staircase at home. Second, little is known about the patterns of coordination that are employed in leg extensor activities. To date, only jumping (Bobbert & van Ingen Schenau, 1988; Hudson, 1986) and speed skating (Koning et al., 1991) have been analyzed in terms of intersegmental coordination. From the data depicted in these studies, it appears that the thigh and shank operate with predominant simultaneity in both these tasks. That is, the thigh and shank both begin and end their propulsive phases at approximately the same times. Presuming a volleyball player wanted to reinforce a simultaneous pattern of coordination, do either stair machines or staircases afford this opportunity? Presuming a person with a hip replacement wanted to rehabilitate with a stair machine. do certain stair machines compare more favorably with staircases in terms of coordination? To gain insight into these and similar questions, the purpose of this study was to investigate patterns of intersegmental coordination in different modes of stair climbing.

METHODOLOGY

The stair climbing devices for this study were chosen from the categories of dependent machine, independent machine, and conventional staircase. The distinction between dependent and independent machine is based on the method of step-rate control during exercise. For dependent devices as well as staircases, the regulation of step-rate is dependent on the exerciser; for independent devices, which are controlled by computer, the regulation of step-rate is independent of the exerciser. In this study the dependent category of stair climbing was represented by the PRECOR 7.4 machine. The independent category was represented by the TETRIX CLIMBMAX and the STAIRMASTER 4000 machines. The final mode of stair climbing was represented by a five-step staircase. Because the staircase had a riser height of 19 cm, the stair machines were constrained to a similar range of motion by placing wooden blocks beneath the steps. In addition, the resistance on the mechanical devices was set to elicit an exercise intensity of 9 mets, and trials were continued until this steady state of exercise was reached.

Two adult females served as subjects. Both were habitual exercisers for health-related fitness and were experienced at using stair climbing machines. Each subject wore close-fitting exercise attire and reflective tape on the right hip, knee, and ankle. Subject 1 performed in all four stair conditions (i.e., PRECOR. TETRIX, STAIRMASTER, STAIRCASE) while Subject 2 performed only on the PRECOR and TETRIX machines.

For each stepping condition a lateral view of the subject was videotaped. A representative stride from the steady-state period of exercise was digitized and smoothed with the PEAK Performance Measurement System. After the angular velocities of the thigh and shank segments were calculated, the extension phase of the right leg was analyzed. For each segment the interval from zero velocity to peak velocity was defined as the period of propulsion, and the interval from peak velocity to zero velocity was defined as the period of post-propulsion. If the thigh and shank segments were in concurrent propulsion during extension, the movement was considered to be simultaneous. If the thigh segment concluded propulsion as or before the shank segment initiated propulsion, the movement was considered to be sequential.

RESULTS AND DISCUSSION

The angular velocities of the right thigh and shank for each subject and stair device axe depicted in Figure 1. For Subject 1 on the PRECOR machine the thigh and shank began propulsion at essentially the same time (0.35 s). Next. the shank reached peak velocity and ended propulsion slightly before the thigh. Finally, both segments concluded the phase of post-propulsion at the same time. Thus, the thigh and shank were operating simultaneously for this subject and this machine. The pattern of coordination for Subject 2 on the PRECOR was also simultaneous during propulsion and post-propulsion. Both subjects had distinct adjustments near the end of the post-propulsive phase. Subject 2 also demonstrated an irregularity in shank velocity near the end of propulsion. Apparently this irregularity is symptomatic for Subject 2 because it also occurred when she exercised on the TETRIX. Nevertheless, she was able to initiate propulsion and terminate post-propulsion simultaneously. Although the shank reached peak angular velocity somewhat before the thigh, this pattern of coordination was predominantly simultaneous. Subject 1 initiated propulsion on the TETRIX with the thigh prior to the shank, but both segments ended propulsion and post-propulsion

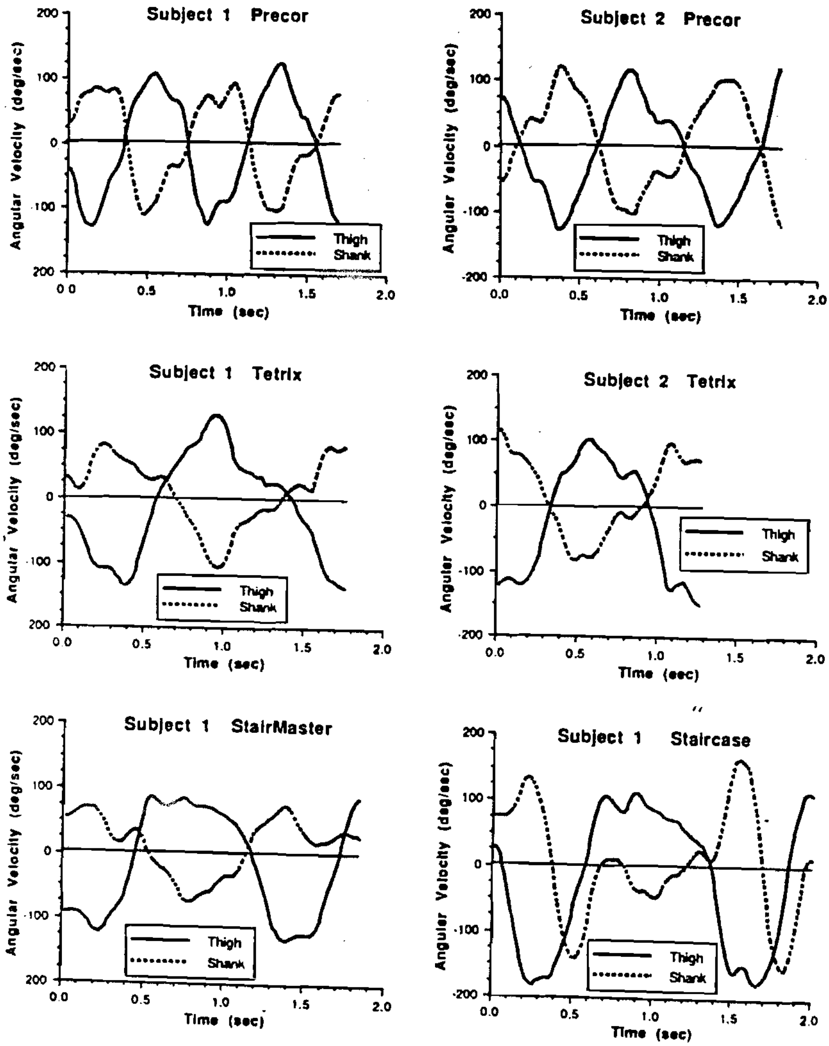

Figure 1. Angular velocity of thigh and shank in each condition.

simultaneously. Once again, both subjects had distinct adjustments in velocity near the end of post-propulsion. While these adjustments are likely related to shifting weight to the left pedal, both subjects reported subjective impressions of awkwardness on the TETRIX. In sum, with the exception of minor idiosyncrasies, both subjects demonstrated similar results on both machines. Although the coordination patterns elicited by the dependent PRECOR and the independent TETRIX were predominantly simultaneous, the pattern from the PRECOR was closer to perfect synchrony.

The velocity pattern from the independent STAIRMASTER was initially similar to that from the independent TETRIX. In both cases the thigh began propulsion about 0.1 s before the shank. At this point the pattern from the STAIRMASTER deviated in that the thigh velocity curve contained twin peaks. The first peak was of higher magnitude and occurred at the same time that the shank initiated propulsion. The second peak was coincident with the termination of propulsion in the shank. The existence of twin peaks complicates the interpretation of coordination. Using a strict interpretation of propulsion (i.e., from zero to maximum velocity) the thigh ended propulsion when the first peak was reached. At that point the shank began propulsion and the pattern could be classified as sequential from proximal to distal. However, at about .6 seconds the thigh resumed propulsion and worked simultaneously with the shank until they both ended propulsion about 0.15 s later. Taken together, the movement on the STAIRMASTER could be classified as part sequential and part simultaneous. The adjustments in velocity near the end of extension that were elicited by the PRECOR and TETRIX were not evident with the STAIRMASTER.

The twin peak pattern was not unique to the STAIRMASTER: It occurred on the staircase as well. In fact, the velocity of the thigh was quite similar on the two devices. The primary difference between the devices was in the pattern of the shank. On the staircase there was a 0.3 s delay between the initiation of thigh propulsion and shank propulsion, and the shank continued in propulsion for 0.1 s after the thigh terminated propulsion. From the time that the thigh initiated propulsion until the time that the shank completed propulsion, there were intervals of thigh-only, neither-segment, both-segment, and shank-only propulsion. For lack of a suitable classification, this pattern could be called part sequential and part simultaneous.

CONCLUSIONS

Within the limitations of classification, the patterns of intersegmental coordination in this study ranged from essentially simultaneous on the PRECOR to predominantly simultaneous on the TETRIX to part sequential/part simultaneous on the STAIRMASTER and staircase. Because the PRECOR elicited an essentially simultaneous pattern of extension in the thigh and shank, this machine might be appropriate for athletes who are cross-training for jumping activities. Both the STAIRMASTER and the staircase elicited complex but relatively similar patterns of coordination. Consequently, the

STAIRMASTER might be appropriate for an individual who is rehabilitating for climbing stairs.

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