AN ANALYSIS OF TWO STAIRSTEPPING MACHINES AT TWO SPEEDS

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INTRODUCTION

Stair-stepping machines have recently become popular for both fitness and rehabilitation. The Stairmaster is often seen in ACL rehabilitation protocols used by physical therapists but is not recommended for all knee conditions. Stairstepping has been shown to add four to six times the body weight to the patellar surface, which may aggravate knee conditions such as chondromalacia (DeBenedette, 1990). All stairstepping machines are not based on the same design, which may affect the rehabilitative process. The Stairmaster 4000PT is an independent machine, with unlinked pedals, pushing down on one pedal has no effect on the other. The Lifestep Model 9500 is a dependent machine, with linked pedals, when one pushes down on one pedal the other pedal is forced to rise. Step height and intensity also vary between designs. With the large number of stairstepping machines on the market, could one design be more appropriate than another during the rehabilitation process?

Cook et al. (1992) have focused on using the stairstepping machine, as a closed kinetic chain exercise, in rehabilitation of the knee. Stairstepping exercises result in concentric action of muscle groups involved in the movement and may appear to be a reasonable means to achieve a more complete lower extremity rehabilitation (DeCarlo et al., 1992). The purpose of this study was to compare the kinematic and kinetic variables of the lower body, during the stairstepping motion, on the Stairmaster 4000PT and Lifestep 9500 at two different intensities.

METHODOLOGY

Twenty-six females (age 20.4 ± 1.6 years; height 167.5 ± 5.3 cm; mass 62.2 ± 8.3 kg) volunteered as subjects. Two-dimensional kinematic data were collected with a Panasonic AG-450 video camcorder positioned in the right sagittal view perpendicular to the Stairmaster 4000PT (SM) and Lifestep 9500 (LS) stepping machines. The high speed shutter was set at 1/500 s and a nominal frame rate of 30 Hz. Reflective markers were placed on the subject's right shoulder, hip, knee, ankle and fifth metatarsal. Each subject stepped at two intensities: "four" is equivalent to 0.40 m/s and "eight" is equal to 0.65 m/s. The subjects were recorded for 10 s on both the SM and LS at a slow intensity (SM4 and LS4) and fast intensity (SM8 and LS8).

After filming the subjects, the Ariel Performance Analysis System, AST 386 computer, and Panasonic 7300 VCR set at 60 Hz were used in digitizing five data points. One complete step on the pedal was captured, digitized, transformed and smoothed. The data were smoothed with a digital filter smoothing package with a cut off frequency of 10 Hz.

The inverse dynamics approach was used to calculate the resultant joint forces at the hip, knee, and ankle. The human body was modeled as a mechanical system composed of four rigid bodies (trunk, thigh, shank, foot) connected by the hip, knee, and ankle joints. Each rigid segment was assumed to move in the XY plane in an inertial reference plane according to Newtonian equations of motion. An ANOVA and

Scheffe's post hoc test were used to analyze the mechanical data.

RESULT and DISCUSSION

Significant differences ($p<0.05$) were found between the machines in the range of motion ROM) of the hip, knee, and ankle (Figure 1). The ROM at each joint was consistently greater on the LS than the SM (Table 1).

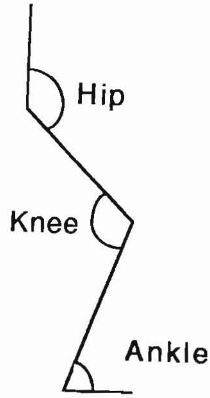

Figure 1. Angle convention for the hip (1), knee (2), and ankle (3).

Table 1. Relative joint angles (°).

Joint	SM4	SM8	LS4	LS8
Hip	25.70	29.06	34.78	35.92
Knee	43.11	45.37	69.04	69.46
Ankle	13.07	20.78	20.70	23.11

The difference in ROM between the machines may be explained by the difference in step height between the machines. The average step height on the LS was 35 to 45 cm, and the step height on the SM was 5 to 30 cm. The joint angle increased on the SM as the speed increased because the pedals were unlinked. This contrasts with the LS where there was very little change in the joint angle at an increased speed. With the LS the subjects go through the full ROM of the machine at all speeds.

The forces at the joints also showed significant differences between the machines ($p<0.05$). These differences were found when looking at compression (COMP), anterior shear (ASF), and posterior shear (PSF) forces (Table 2). There were significant differences between the machines in the COMP forces, although, the differences were not significant for the TENS forces. On both machines as the speed increased so did the COMP forces. Greater COMP forces and less TENS forces were produced on the LS. These differences may also be attributed to the dependent and independent design of the machines. On the LS as one pedal reaches the top of the stroke the other pedal reaches the bottom. The SM is independent with no force from the resting pedal, this may cause greater COMP forces on the LS. The greater TENS forces on the SM may occur because the subject has to lift the leg to return it to the starting point on the SM, while the LS will push the leg up without assistance from the subject.

Table 2. Mean joint forces (N).

	LS4	LS8	SM4	SM8
Hip				
COMP	144.5	148.7	111.9	133.1
TENS	-16.2	-13.4	5.9	-8.5
ASF	65.6	55.5	46.5	37.9
PSF	-47.9	-56.7	-50.6	-44.6
Knee				
COMP	302.9	325.0	233.5	270.3
TENS	-30.5	-27.2	10.8	-4.2
ASF	127.1	109.0	83.1	77.4
PSF	-104.1	-108.2	-80.0	-64.8
Ankle				
COMP	381.9	414.4	299.5	347.6
TENS	-18.8	-18.8	24.5	11.2
ASF	138.1	116.6	97.3	132.6
PSF	-111.9	-111.9	-89.0	-71.0

The ASF and PSF were less on the SM than the LS. ASF was the femur moving posteriorly on the tibia. Cook et.al. (1992) found that co-contraction of the quadriceps and hamstrings were promoted by a closed kinetic chain activity. Co-contraction may have worked to minimize this displacement of the femur. The difference in the dependent and independent steps on the machines may affect the amount of co-contraction. The greater ROM on the LS will affect the shear forces incurred at the joints. The shear forces decreased, on both machines, when the speed increased .

CONCLUSIONS

The LS created greater ROM in the hip, knee, and ankle joints contributing to larger shear forces than seen in the SM. The LS machine had greater COMP forces and the SM had greater TENS forces. These differences may be because of the amount of co-contraction of the hamstrings and quadraceps muscles, which we were unable to measure, and/or the differences between the independent and dependent design of the SM and LS machines. Differences may also be attributed to the kinetic model, as an external force from the machine may be contributing to the joint forces.

It appears that, from a rehabilitative standpoint, the SM would be the preferred machine to use to start rehabilitating a person who has undergone ACL repair. Engle et al. (1992) found that weight bearing decreased ACL stress through quadriceps/hamstring co-contraction and less ASF with the SM although deep flexion was more likely to cause patellofemoral symptoms.

More research must be done to determine which machine may be appropriate for specific injuries. Electromyography and joint moments could provide additional data for the physical therapist, athletic trainer, and physician in prescribing the correct protocol to assist in an earlier recovery time for the injured individual. Force transducers applied to the pedals and arm handles should be used to verify the resultant joint forces found in this study.

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