AN ANALYSIS OF THE ERGOMETER AND RECUMBENT CYCLES IN TWO DIFFERENT SEAT POSITIONS

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INTRODUCTION

The bicycle ergometer has been used as a fitness and rehabilitative tool by many individuals. The recumbent bicycle, a relatively new ergometer, is also being used in this capacity. Although there has been a surge in research on the stationary bicycle, the majority of it has been oriented toward fitness rather than rehabilitation. Ericson, Nisell, and Gunner (1988) suggest that the bicycle is an useful therapeutic device because it increases range of motion (ROM) at the hip, knee and ankle joints and reduces compressive forces on the lower body. Mechanical loads placed on different joint structures can be controlled by changes in the workload, pedaling rate, or seat position of the ergometer. Timmer (1991) found that increased seat height produced greater ROM with increased stress on the anterior cruciate ligament of the knee but, decreased seat height reduced patellofemoral pressure and compressive forces at the tibiofemoral joint. There is no doubt that the exercise cycle is becoming more widely used, but the protocols for its use in rehabilitation have not been tested. Thus, the purpose of this study was to compare the kinematic and kinetic variables of the lower body, during the cycling motion, on two different cycles at two different seat positions. Additionally, to determine if specific cycles may produce unwanted stresses on the lower body during the rehabilitation process.

METHODOLOGY

Twenty females (age 20 ± 1.6 yrs; height 167.1 ± 5.3 cm; mass 61.8 ± 9.5 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 Life Cycle ergometer (ERG) and the Life Cycle recumbent (REC) bike. 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 rode both the ERG and REC at two different seat positions: large angle (knee flexed between 40° and 50°) and small angle (knee flexed between 10° and 20°). The subjects were recorded for 10 s on both the REC and ERG at an increased seat position (RSA and ESA) and at a decreased seat position (RLA and ELA).

After filming the subjects, the Ariel Performance Analysis System, AST 386 computer, and Panasonic 7300 VCR set at 60 Hz were used in digitizing 5 data points. One complete revolution of 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 4 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 (Figure 1). An ANOVA randomized blocks design with the Scheffe post hoc test was used to analyze the mechanical data.

RESULTS and DISCUSSION

Angles of interest in this study were the relative angles of the hip, knee, and ankle (Figure 1). Increased range of motion (ROM)occurred at the hip, knee, and ankle joints for the higher seat position (SA) on both cycles. Additionally, increased ROM was observed with all joints on the REC cycle as compared to the ERG with the exception of the RSA and the ESA at the ankle joint (Table 1). At the hip joint, a significant difference was seen between the cycles, but no significant difference was seen within the cylces at the two different knee angles. There was increased ROM at the hip joint on the REC cycle because of the horizontal orientation of the body. In the early stages of knee or ankle rehabilitation, it would be more beneficial for a patient to exercise on the ERG rather than the REC and at a lower (LA) rather than a higher(SA) seat position to reduce the ROM. As the patient progressed, the seat could be raised gradually on the ERG or the patient could be moved to the REC in order to increase ROM and muscle strength.

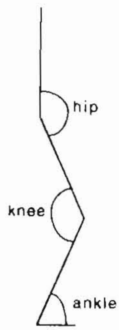

Figure 1. Angle conventions.

Significant differences ($p<0.05$) occurred in the resultant joint forces of compression (COMP), tension (TENS), anterior shear (ASF), and posterior shear (PSF) under the 4 different conditions. Greater COMP forces were observed at the hip on the ERG, however, more negative aspects were associated with the REC. Increased TENS force occurred at the hip,knee,and ankle joints while increased ASF occurred at the knee and ankle joints (Table 2).

Table 1. Range of motion (°).

	RSA	RLA	ESA	ELA
Hip	45.9	45.2	40.0	40.8
Knee	76.6	68.5	72.2	61.3
Ankle	30.6	22.2	34.3	20.5

Greater COMP force occurred at the hip on the ERG because the subject is seated in a more vertical position, therefore, increased direct COMP force was applied at the hip. The recumbent cycle had more TENS force because of the horizontal orientation of the body. This horizontal movement of the lower limb also causes more PSF at the knee since the femur is sliding posterior on the tibia. These resultant joint forces have indicated that the REC cycle placed increased and potentially harmful stresses on all of the joints. This may be because of the horizontal position that the body is placed in on the REC cycle. A limitation to the model was the application of force from the pedals by the machine which may have influenced the reported resultant forces at each joint.

Table 2. Mean resultant joint forces (N)

		RSA	RLA	ESA	ELA
Hip					
	COMP	121.7	125.4	144.2	149.7
	TENS	-4.5	-7.9	-23.0	-21.6
	ASF	37.5	40.6	52.4	39.4
	PSF	-38.4-	40.6	-49.6	-40.2
Knee					
	COMP	285.1	286.5	291.3	299.7
	TENS	-13.8	-15.8	-68.8	-57.9
	ASF	83.9	84.7	83.2	70.6
	PSF	-87.8	-99.7	-85.1	-68.7
Ankle					
	COMP	398.7	402.0	390.0	407.9
	TENS	-21.5	-19.3	-107.1	-115.1
	ASF	89.3	92.3	83.8	75.7
	PSF	-123.6	-136.1	-95.5	-102.8

Angular velocities (AV) were measured at the thigh, shank, and foot segments (Table 3). Significant differences were found at all segments between the RLA and the ESA. In addition, a significant difference also occurred at the foot between the RLA and the ELA. Increased AV occurred at the thigh on the REC cycle, but greater AV on the ERG occurred at the shank and foot. Increased ROM, in a shorter time period, produced greater AV as the subjects completed each revolution.

Table 3. Angular velocities of the thigh, shank, and foot (°/s).

	RSA	RLA	ESA	ELA
Thigh	152.4	167.6	138.3	159.7
Shank	136.9	136.8	153.1	160.9
Foot	241.7	212.7	258.0	271.5

The crank speed for both cycles was at "four", however, this may also be a contributing factor to the AV noticed at each joint between the cycles.

CONCLUSIONS

The results of this study have indicated that, in most cases, the ERG is a better rehabilitative tool than the REC. The data showed that the ERG was the preferred cycle because of decreased ROM of the joints, as well as decreased tensile and anterior/posterior shear forces. These results have not clearly indicated which seat position is most beneficial to patients at various stages of rehabilitation for reduced forces at each joint.

These results provide important implications for instructing people on correct seat heights and specific cycles to be used for the desired ROM and for the reduction of forces on the joints that could prove to be harmful. Further research will include the application of force transducers to the pedals and EMG to verify the current model. From these results, protocols may be established to determine the exact seat height that would be beneficial to the patient in rehabilitation.

Not only are stationary bicycles seen in the rehabilitation setting, but they continue to be a major instrument in the area of fitness. It should be kept in mind, however, that although an aerobic workout as well as recovery from various injuries may be gained through cycling, there could be simultaneous damage occurring at the lower body joints if the seat is not positioned to the proper level or if the wrong type of cycle is used.

REFERENCES

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