STEP AEROBICS: A KINEMATIC AND KINETIC ANALYSIS

S. A. Bezner, S. A. Chinworth, D. M. Drewlinger, J. C. Kern,
P. D. Rast, R. E. Robinson, J. D. Wilkerson

Texas Women's University
Denton, Texas, USA

INTRODUCTION

Stepping activities were first introduced in the early 1980s. Since that time, stepping has become a very popular means of aerobic exercise. One of the most recent forms of stepping exercise is step aerobics. Participants follow a routine which involves stepping up and down on steps of varying heights, at varying cadences, in order to achieve an aerobic workout. Much literature has been published in regard to the aerobic benefit of stepping and step aerobics. However, few studies have been conducted investigating biomechanical factors involved in this activity.

One published study (Francis et al., 1990) compared the peak ground reaction forces (GRF) of stepping on and off a 0.25 m platform at 120 steps/minute (SPM) to walking at 4.8 kilometers/hour (kph) and running at 11.2 kph. In another study (Newton and Humphries, 1991), resultant peak GRF were compared during stepping at 0.2 m, 0.25 m, and 0.30 m at 120 SPM, stationary walking and jogging. Both studies reported that the greatest forces were experienced during running, followed by stepping and walking. Additional information from preliminary work performed at San Diego State University (Power Step Reebok[R], 1992), has stated that impact forces during step aerobics were comparable to those found during three mph walking. From these data, it was concluded that the injury risk involved with step aerobics was relatively low. Based on these few published studies, the amount of biomechanical research performed on the activity of step aerobics has been limited. Additional studies to address questions of safety, progression, cadence, and step height are warranted. Therefore, the purpose of this study was to investigate selected kinematic and kinetic variables during step aerobics at varying heights and cadences.

METHODOLOGY

Nine females, mean age of 25.2 ± 4.3 years and mean height of 164.8 ± 4.5 cm, participated in the study. Subjects had no prior history of lower extremity injury and each subject signed an informed consent form. Subjects performed cycles of conventional aerobic stepping with each cycle consisting of right foot up, left foot up, right foot down, and left foot down. Each subject performed three consecutive cycles of aerobic stepping on a Reebok Step™ at heights of four, six, and eight inches and cadences of 100 and 120 SPM. A metronome was used to maintain the cadence. Randomization of trials was determined by a Latin square design.

A Locam high-speed camera (Model 51, Redlake, Ca.) was located perpendicular to the right sagittal plane of the subject's body. The cinematographic data were collected at 90 frames/second and digitized to determine coordinates for the greater trochanter, femoral epicondyle, lateral malleolus, calcaneus, and fifth metatarsal. A Kistler force platform was used to record the GRF of the right foot during step down. The force data were sampled at 100 Hz and dilated to match the film data. One cycle of each trial was used to calculate joint forces. A three link segment model was used to calculate the forces and moments at the hip, knee, and ankle. All segments were assumed to be rigid.

Data were analyzed with a two-way repeated measures ANOVA across conditions (step height and cadence) for peak moments and peak vertical joint forces at the ankle, knee, and hip.

RESULTS

Means for the peak vertical joint forces and peak moments at the three lower extremity joints are presented in Table 1. A significant difference was found in the peak vertical joint forces between step heights at all three joints ($p<0.05$). A Tukey post hoc analysis revealed that each increase in step height produced an increase in vertical joint force. No differences were found when stepping speed was increased. The magnitude of the vertical joint forces at the ankle, knee, and hip did not differ significantly.

Table 1. Mean peak vertical joint forces and moments.

		Vertical Joint Forces (BW)			Moments (Nm)		
Step Height	Cadence	Ankle*	Knee*	Hip*	Ankle	Knee	Hip
4 in.	100 SPM	1.64	1.50	1.70	119.9	84.1	217.3
	120 SPM	1.65	1.62	1.70	119.9	86.9	241.3
6 in.	100 SPM	1.75	1.71	1.81	140.2	71.9	220.4
	120 SPM	1.76	1.72	1.81	127.7	81.0	222.8
8 in.	100 SPM	1.91	1.84	1.90	147.0	71.5	230.5
	120 SPM	1.87	1.95	1.96	138.8	78.5	205.4

* $p<0.05$ across step heights

The ANOVA revealed no significant differences in the peak moments at any of the three joints with respect to increases in height or cadence. Examination of the moments indicated a similar pattern among all subjects at the ankle, and oscillating patterns at the knee and hip (Figure 1). GRF increased as step height increased. The values recorded were 1.60 times body weight (BW), 1.66 BW, and 1.76 BW at four, six, and eight inch heights, respectively. The increase in cadence from 100 SPM to 120 SPM had no effect on GRF.

DISCUSSION

The GRF in this study were similar to the 1.75 BW vertical GRF found by Francis et al. (1990). Their step height of 0.25 m was almost two inches higher than the highest height used in this study. The GRF of all three heights in the present study were similar to those reported by Newton and Humphries (1991) for walking, but were less than those reported for jogging and stepping. Their resultant peak GRF were reported as 1.75 BW for walking, 3.07 BW for jogging, 2.24 BW for stepping at 0.20 m, 2.43 BW at 0.25 m, and 2.90 BW at 0.30 m. These authors attributed their increased forces, compared to Francis et al., to using resultant forces which took into account the anterior/posterior in addition to the vertical GRF.

The magnitudes of the joint reaction forces in this study were similar between the two cadences. Although significant differences were found between the step heights, the magnitudes of the joint forces were similar across the joints at each of the three heights. This indicated a lack of dissipation of force across the joints, distal to proximal, which may be a risk factor for injury in step aerobics.

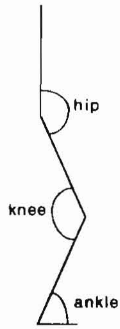

Figure 1. Joint moment patterns of the ankle, knee, and hip (six inch height and 100 SPM).

The oscillation of joint moments at the hip and knee may be attributed to noise and error associated with the calculation technique. However, examination of the film indicated oscillating joint motions at the knee and hip as weight was accepted onto the right leg. Therefore, the oscillating patterns shown by the subjects may indicate that these joints were used uniquely by the individuals in stabilization of the body during the step-down.

CONCLUSIONS

This investigation of kinetic and kinematic variables involved in normal step aerobics suggested that increase in cadence from 100 to 120 SPM may not be a contributing factor to risk of lower extremity injury. As expected, joint forces increased as step height increased. Thus, the normal progression in step height might be an injury risk factor due to the lack of force dissipation across the lower extremity. Since only one trial per subject per condition was used in the analysis, conclusions of this study should be considered speculative. The results of this study and the increased popularity of this form of exercise indicate the need for continued research, with additional emphasis placed on the step up phase.

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