KINEMATIC ANALYSIS OF FIVE CARDIOVASCULAR EXERCISES

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INTRODUCTION

Cardiovascular (CV) exercise remains a key component of national health efforts aimed at preventing chronic and secondary medical complications in people of all abilities. While there are several equipment options available for use, a variety of individual factors (e.g., fitness goals, physical impairments) can complicate selection of appropriate training devices. A clear understanding of the biomechanical demands imposed by common CV exercise equipment should help guide device selection. In our previous work [1-3], we highlighted how muscle effort (peak, mean, duration) varied across five commonly performed cardiovascular exercises. The purpose of the current study was to explore lower extremity sagittal plane kinematic demands arising during the same cardiovascular exercises.

METHODS

Ten individuals (19-31 years of age; 6 male) with no known musculoskeletal or neurological disorders participated in a multi-session study. During the first three sessions, subjects walked and jogged on a treadmill (**TW** and **JG**; Life Fitness™ 97Ti) and trained on an elliptical cross-trainer (**EL**; Life Fitness™ 95Xi), recumbent bicycle (**RB**; Life Fitness™ 95Ri), and stairstepper (**SS**; Life Fitness™ 95Si) for familiarization purposes. During the fourth session, dominant limb lower extremity kinematics (Motion Analysis, Santa Rosa, CA) were recorded as subjects performed each exercise at a self-selected speed. All activities were performed for three minutes in a randomized order and data were recorded during the final minute. Footswitch (TW and JG) and footplate kinematics (EL, RB, and SS) defined movement cycle (MC) phasing. MCs were defined by the instant of heel contact to the next ipsilateral heel contact (TW & TJ) and the most anterior (EL), posterior (RB), and superior (SS) footplate positions to their next respective positions. Peak flexion and extension angles that occurred throughout the movement cycle were identified for each activity at the hip, knee and ankle.

STATISTICAL ANALYSIS

Separate one-way analysis of variance (5 x 1 ANOVAs) with repeated measures determined if peak angles varied significantly across the five conditions at each joint.

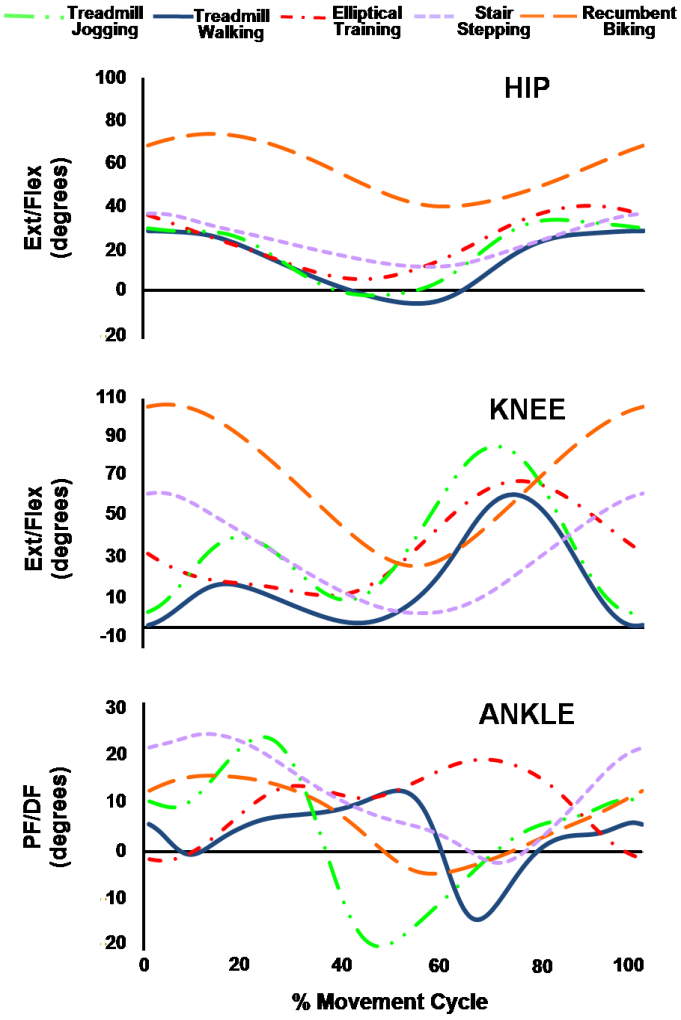

Figure 1. Ensemble averaged (mean) kinematic plots of sagittal plane hip, knee, and ankle motion while performing cardiovascular exercises (n=10).

RESULTS AND DISCUSSION

Kinematic profiles for each exercise activity are presented in Figure 1. At the *hip,* all activities started in flexion which lessened to a nadir during the middle of the MC and then progressively increased prior to the MC's termination. The hip's arc of motion was greatest during EL (49º) and shallowest during SS (34º). Peak hip flexion and extension demands varied significantly across activities (Table 1). At the *knee,* three movement patterns were apparent. TJ and TW displayed characteristic bimodal profiles. Following near full extension at initial contact, rapid flexion preceded the first flexion peak during early stance that approximated ½ to ⅓ the amplitude of the respective second peak that occurred during swing. Nearly full knee extension was achieved prior to the next initial contact. In contrast, RB and SS displayed unimodal patterns. Peak flexion occurred close to onset of the MC. Maximal extension was achieved at approximately ⅔ of the MC. The EL movement profile was a hybrid of the two previous patterns. The knee started in approximately 35º of flexion and then extended until approximately 36% of the MC at a rate more gradual than that occurring during the single limb support period of TW and TJ. Knee flexion in the latter half of the MC most closely approximated that of walking. The largest arc of knee motion occurred during TJ (78º), while EL required the smallest arc (59º). Peak knee flexion and extension demands varied significantly across exercises (Table 1). *Ankle* movement profiles appeared disparate across activities although a close examination suggests some similarities. TJ and TW cycles were initiated with brief motion towards plantar flexion, followed by progressive dorsiflexion as body weight progressed across the foot. A rapid plantar flexion wave characterized the stance-swing transition followed by achievement of a dorsiflexed ankle during swing. SS and RB demonstrated unimodal patterns. Maximal dorsiflexion occurred in early stance and maximal plantar flexion was achieved in the latter half of the MC. During EL, the ankle remained primarily in DF, with the pattern in early stance somewhat approximating that achieved during walking. TJ necessitated the greatest arc of sagittal plane ankle motion (44º), while RB required the shallowest (22º). Peak plantar flexion and dorsiflexion demands varied significantly across activities (Table 1).

CONCLUSIONS

The significant variations in motion demands documented across cardiovascular exercises in the current study provide empirical data to guide selection of exercise interventions to promote therapeutic goals. For example, if full hip extension induces undesirable pain, then RB and SS may provide opportunities to achieve cardiovascular goals while minimizing pain. Alternatively, the gentle repetitive stretch on anterior capsule structures during EL may offer a means for progressively elongating a flexible hip flexion contracture. Further research exploring the application of select cardiovascular exercises on reducing range of motion impairments is warranted.

REFERENCES

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Table 1. Comparison of peak flexion/extension angles achieved at hip, knee and ankle during cardiovascular exercise. Note: positive values (+) = flexion or dorsiflexion; negative values (-) = extension or plantar flexion.

	Peak Position	RB	EL	SS	TJ	TW	Significant Main Effect
HIP	Flexion	96 (13)	54 (5)	48 (8)	44 (3)	38 (4)	RB > TJ, TW; EL > TW
	Extension	51 (10)	5 (4)	14 (6)	-4 (6)	-9 (5)	TW, TJ, EL > RB; TW > SS
KNEE	Flexion	107 (5)	71 (3)	66 (10)	87 (9)	65 (4)	RB > TJ > EL, SS, TW
	Extension	29 (9)	12 (4)	6 (8)	6 (4)	-2 (4)	TW > SS, TJ, EL > RB
ANKLE	Dorsiflexion	17 (10)	25 (6)	25 (7)	24 (3)	13 (3)	EL, SS > TW
	Plantar Flexion	-5 (6)	-4 (4)	-4 (7)	-20 (7)	-15 (5)	TJ, TW > RB, EL, SS