A Concentric and Eccentric Loading Regime for Shoulder Rehabilitation

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INTRODUCTION

The application of linear impulse and momentum as a means for exercise, rehabilitation and physical therapy has been previously demonstrated (Phillips et al., 2000). This technique uses inertial forces generated as actions and reactions to a weighted shuttle traveling on a horizontal rail system. The objectives of this study were to: 1) quantify the net shoulder joint forces and moments while using an impulse-momentum exercise system; and 2) test the influence of gender and muscle loading type (concentric or eccentric) on kinetic parameters.

METHODS

Exercise Regimen

Fourteen healthy adults (8 males, 6 females) were selected as subjects (mean age, 35 years). Each subject was tested utilizing a 10 cycle protocol repeated for 2 to 6 trials. Test subjects were seated (Biodex, Shirley, NY) with their dominant arm supported in 90^o of abduction (Figure 1). The subjects' flexed arm was placed in a neutral position (corresponding to 0^o) by positioning the forearm parallel to the floor and extended toward the impulse exercise system (**A**). While maintaining 90^o of shoulder abduction, the subjects externally rotated their upper arm from neutral to 90^o (perpendicular to the floor) causing the shuttle (22.2 N) to move from one end of the track to the central position (**B**). The subject then internally rotated their arm from 90^o to the initial position while maintaining a braking force in the rope as the momentum of the shuttle carried it to the opposite end of the track, completing a cycle (**C**). Tension was maintained in the cabled shuttle system at all times during the exercise. The outcome of this activity is a transition from concentric to eccentric loading during external and internal rotation, respectively. The data were collected at a sampling rate of 100 Hz and cycles 2 through 9 were analyzed.

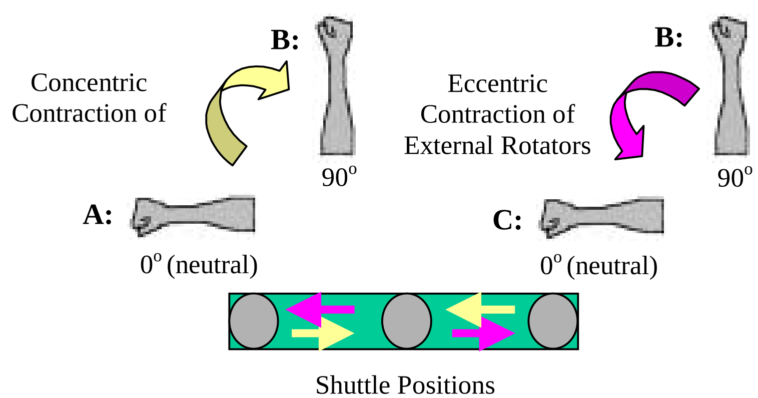

Figure 1: Schematic of arm position (side view) with respect to shuttle position (top view). See Methods for description.

Shoulder Calculations

The limb dimensions and masses of the 14 subjects were not available. Therefore, the anthropometric data used for the following calculations consisted of limb center of mass (Winter, 1990) and the 50th percentile limb dimensions and weights of U.S. adult civilians (Kroemer, 1989). The net shoulder joint reaction forces were calculated by applying Newton's Second Law of motion due to limb mass m and acceleration **a**. The net shoulder moments were calculated by applying the rotational analogue of Newton's second law of motion due to the moment of

Inertia I about the axis of rotation and the angular acceleration α relative to that axis.

The work done by the shoulder was incrementally calculated from the resultant moment and rotational data. Work was defined as:

$$W = \int \mathbf{m} \cdot d\theta, \quad (1)$$

where **m** is the average moment of two consecutive samples and $d\theta$ is the angular distance the forearm traveled in the 0.01-s period between samples. The power delivered by the shoulder during the concentric and eccentric phase of the exercise was then calculated by the expression:

$$P = dW/dt = \mathbf{m} \cdot (d\theta/dt). \quad (2)$$

Data Analysis

In order to identify peak net forces and moments at the beginning and end of each phase (concentric 0º-90º and eccentric 90º-0º) of motion, each phase was further subdivided into concentric (0º-45º and 45º-90º) and eccentric (90º-45º and 45º-0º) segments. A repeated measures ANOVA was conducted to assess the effects between factors (gender and subject) and within factors (muscle loading, loading phase, trial, cycle). A P-value ($P \leq 0.05$) indicates statistical significance.

RESULTS AND DISCUSSION

Overall concentric peak forces and moments were greater than eccentric peak forces and moments ($P<0.0001$, Table 1). Joint forces and moments reached a maximum during the initial phase of concentric loading (0º to 45º) compared with any other rotational position in the loading cycle (concentric 45º-90º or eccentric 90º-0º). The results also indicate that males experienced higher ($P<0.0001$) average resultant peak joint reaction forces than females. Moreover, males experienced higher ($P < 0.0001$) average resultant peak joint reaction moments than females.

The repeated measures analysis revealed that work and power performed by males was statistically similar to work and power performed by females ($P=0.0665$). However, the difference between concentric and eccentric work and power for all subjects was statistically different ($P<0.0001$).

SUMMARY

The shoulder joint mechanics of the impulse inertial exercise have been successfully quantified. The results of this study will aid therapists in the monitoring of patient rehabilitation by providing them with the essential force and moment information.

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Table 1:

		Resultant Average Peak Shoulder Joint Forces (N)				Resultant Average Peak Shoulder Joint Moments (N m)			
	Cycles	Concentric Phase		Eccentric Phase		Concentric Phase		Eccentric Phase	
		0º-45º	45º-90º	90º-45º	45º-0º	0º-45º	45º-90º	90º-45º	45º-0º
Males	208	302.1 ± 84.3	267.2 ± 91.5	261.8 ± 96.0	236.5 ± 77.1	84.4 ± 23.5	76.6 ± 24.2	64.8 ± 32.5	66.1 ± 20.6
Females	176	186.6 ± 52.2	136.3 ± 32.4	149.7 ± 50.1	150.5 ± 46.4	45.6 ± 10.2	40.5 ± 16.9	32.2 ± 13.8	37.6 ± 11.4
All subjects	384	249.2 ± 91.7	207.2 ± 96.3	210.4 ± 96.2	197.1 ± 77.7	66.6 ± 26.9	60.1 ± 27.8	49.9 ± 30.4	53.0 ± 22.1