BIOMECHANICAL COMPARISON OF RUNNING IN LAND AND WATER MEDIA

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INTRODUCTION

Running is a principal component of many forms of physical activity, playing a major role in fitness development and as a primary training mode for numerous athletic activities (Bates, 1979). However, running cannot be a totally injury-free activity. During the physical act of running, the human body incurs a number of repetitive forces or stresses, which in turn are frequent sources of injury. The impact force that occurs when a runner continually exposes the lower extremities to a force two to three times greater than body weight is a major factor associated with foot and leg injuries. When heelstrike is linked with joint degeneration, force transmission during running is a likely source of skeletal damage (Cavanagh, 1990). Recently, new training techniques have been developed which enable runners to avoid the stresses associated with repetitive hard surface impacts. One of these techniques includes running in a vertical position while moored buoyantly in deep water, based upon the assumption that this technique will provide cardiovascular and biomechanical training comparable to standard running activities without the related stresses associated with foot strikes upon hard surfaces. It has also been posited that in water, buoyancy will allow for a wider range of motion, increased flexibility, and reduced joint stress, resulting in a decrease in the chance of injury during exercise (Manfredi, 1984).

In general, research efforts that have been undertaken to measure the effects of exercise in water environments have been physiologically based and associated with swimming and/or simulated weightlessness. Town (1991) has suggested that biomechanical comparisons should be undertaken for exercise in water media. Thus, the purpose of this study was to compare the kinematic effects of running conducted on land and in water media.

METHODOLOGY

Four pilot studies were undertaken to establish a standard methodology for a water medium, encompassing the evaluation and comparison of the mechanics of land to water running (Griffin, 1991). Comparisons were based upon the Borg (1982) Rating of Perceived Exertion (RPE). Subjects for the current study consisted of a male and female, ages 30 and 26, respectively, who were free of injury or other physical impairment. Both subjects were skilled swimmers as well as runners, who each ran a minimum of 35 miles per week on land and regularly trained in water. Subjects had a good understanding of RPE and used it as a competitive training tool.

Evaluation of joint angles involved the synchronization with two video recording devices. Prior to the experimental procedures, 10 markers were placed on the sagittal side joint centers of each subject: below the acromion process at 1/2 and 1/3 of the distance to the elbow, and at the shoulder, elbow, wrist, fifth phalange, hip, knee, ankle and the fifth phalange of the toe. In addition, body fat

Table 1. Land and Water ROM Values at Varied RPE.

Joint	DW 13		TM 13		DW 18		TM 18	
	S2	S1	S2	S1	S2	S1	S2	S1
Ankle	29.2	37.6	32.5	71.9	36.5	25.3	31.6	67.2
	(3.3)	(5.2)	(3.8)	(2.6)	(3.8)	(4.1)	(3.4)	(1.7)
Knee	106.1	103.4	109.7	103.9	108.5	98.7	127.3	110.5
	(3.0)	(3.1)	(3.8)	(1.8)	(2.3)	(1.8)	(4.0)	(2.3)
Hip	57.1	29.1	42.1	51.4	51.5	33.1	50.5	49.3
	(2.4)	(3.7)	(1.1)	(2.0)	(2.6)	(3.5)	(2.2)	(2.1)
Shoulder	57.5	52.0	69.5	59.4	73.0	59.3	68.3	69.6
	(3.6)	(2.0)	(2.0)	(4.4)	(2.0)	(2.4)	(2.1)	(5.4)
Elbow	41.9	18.7	31.1	61.5	50.3	32.1	30.9	41.9
	(5.5)	(6.6)	(4.4)	(12.9)	(3.0)	(3.5)	(3.9)	(8.3)
Wrist	26.1	19.2	19.6	42.7	16.9	15.4	25.8	31.4
	(4.6)	(2.8)	(2.3)	(8.8)	(2.5)	(3.8)	(3.9)	(9.3)

(Results (in degrees) are the means for five trials, standard deviations listed below in parentheses.)

measurements, heart rate data, blood pressures, and training records were recorded for each subject. Heart rates were monitored for evaluation of intensities and for immersion effects with a Polar Accurex at 13, 15, and 18 RPE at both the beginning and ending of a one-minute period of maintained RPE. Land collection was completed with a Precor 9.4 SP Treadmill (TM), with the speed selected by the subject to achieve the desired RPE. Water collection was completed in the deep end of a pool with the aid of a Hydro-Fit buoyant device, located at the ankle areas. Deep water running was based upon running in a vertical position while suspended in deep water (DW) with both cadence and intensity self-selected by the subject. Five trials for each the suspended deep water and treadmill conditions were videotaped at both 13 and 18 RPE, with heart rates recorded at rest and for all RPEs. Data were manually digitized with the Ariel Performance Analysis System for land and water experiments at 60 and 30 Hz, respectively. The 30 Hz data were interpolated to 60 Hz and smoothed, using a ninth-order polynomial, and derivatives were calculated. Between subject comparisons were evaluated with t-test ($p<0.05$) and within subject comparisons conducted with a Model Statistic technique (Dufek, 1991).

RESULTS AND DISCUSSION

Descriptive data (ROM) are given by subject-joint in Table 1. A summary of significant statistical comparisons are given in Table 2.

In the water, the 18 RPE reflected a higher percentage (89%) of significant changes across joints than 13 RPE. Minimum, maximum, and joint ROM values were 83, 83, and 100% significant differences across subjects for 18 RPE. Similar comparative values for 13 RPE in the water were 67, 83, and 83% significance, respectively. In contrast, 13 RPE on land reflected a higher percentage of

Table 2. Statistical Summary for ROM, Minimum, and Maximum.

ROM (Between Subject)	Ankle	Knee	Hip	Shoulder	Elbow	Wrist
DW @ 13 RPE	*		*	*	*	*
TM @ 13 RPE	*	*	*	*	*	*
DW @ 18 RPE	*	*	*	*	*	
TM @ 18 RPE	*	*			*	
ROM (Within Subject)						
TM vs DW @ 13 RPE	1		1 2	1 2	1 2	1 2
TM vs DW @ 18 RPE	1	1	1 2	1	1	1 2
13 vs 18—TM	1	1 2	2	1	1	2
13 vs 18—DW	1 2	1	2	1 2	1 2	2
Minimum Joint Position						
TM vs DW @ 13 RPE	1	1 2	1 2	1	2	1 2
TM vs DW @ 18 RPE	1 2	1 2	1 2	2	1 2	1 2
13 vs 18—TM		1 2	2		2	2
13 vs 18—DW					1 2	2
Maximum Joint Position						
TM vs DW @ 13 RPE	1 2	1 2	1 2	1 2	1 2	2
TM vs DW @ 18 RPE	1	1 2	2	1 2	1 2	2
13 vs 18—TM	1			1	2	2
13 vs 18—DW	1 2	1	1 2	1 2	2	1

Statistically significant at $p < 0.05$.

(Note: 1 = subject 1 within subject, 2 = subject 2 within subject, * = between subjects)

significant changes across joints (83%) than 18 RPE. The greatest changes for ROM between land and water exercises were observed at 13 RPE. Because the arms provide lift during running (Cavanagh, 1990), changes in the upper extremities due to the change in resistance from the water to the air media were anticipated. The results suggest that when subjects attempted to increase RPE in the water, the ROM in the upper extremity joints increased.

Table 1 illustrates mean ROM changes for all joints in both TM and DW at RPE 13 and 18. Unlike the upper extremities, the lower extremity ROM values did not increase for both subjects across the joints. This effect was perhaps due to the use of a buoyant device, which increased resistance at the lower extremities and made running in the water more difficult. Different strategies were observed for the water medium when comparing subjects. With exception of the wrist joints, both subjects employed increased ROM in the upper extremities. The wrist joint decrease in ROM may be partially attributed to increased resistance and decreased ROM, during the observed hand opening actions. Individual subject techniques were more readily observed in the lower extremities. Subject 1, evidencing a low knee and backward kick, increased running intensity by increasing the speed of the lower extremities, in contrast to Subject 2, who used a high knee and forward kick to increase intensity by increasing the ROM for the lower extremities. On land, both subjects increased intensity by an increase in speed and displayed similar patterns when increasing RPE. Decreases in ankle ROM accompanied by increased knee ROM were observed. In addition, both subjects demonstrated an opposing movement pattern for the hip and shoulder.

CONCLUSIONS

From the data analyses, differences in joint angles and ROM were of sufficient significance to suggest that treadmill running and suspended deep water running differed in a number of important respects, exhibited as changes in form as the workload was increased. It was initially assumed that treadmill running would require increased stride length to maintain position as speed was increased, while in water, due to the resistance of the medium, it was conjectured that the ROM would be increased and magnified. From the results of this study, the first assumption was clearly demonstrated. However, the second conjecture remained ambiguous. Although Subject 2 displayed increased ROM for some joints in the water medium, Subject 1 consistently demonstrated increased ROM for land running and not for those in water. What is clear from this experiment is that running in a water media clearly magnifies individual differences (i.e., 13 and 18 RPE = 78 and 89%, respectively). These results support the hypothesis that subjects will adjust their running techniques for exercise in a water media. Variations in running form were observed and these differences were further magnified with an increase in RPE, suggesting that water may be used as an alternative exercise program as well as possibly for rehabilitative purposes.

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