KINEMATIC ANALYSIS OF MIDDLE-DISTANCE RUNNERS DURING TREADMILL RUNNING AND DEEP WATER RUNNING

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The present study compared the kinematics of treadmill running (TR) with deep water running (DWR). Five male middle-distance runners of national level were requested to run in Intensities of regenerative effort, long aerobic, 5/10 km, 400/800 m and 100/200 m on treadmill and water. Three complete running steps were recorded. Two-dimensional analysis methods were employed to analyse the lower limb movement and general kinematics. The results revealed diferences ($p<0.05$) between TR and DWR on angular velocity and range of motion (ROM) of lower limb in most of running intensities, except in shank angular ROM on regenerative and long aerobic intensities, and thigh angular ROM on 100/200m intensities, where statistical differences were not observed. These findings suggest that the kinematics of DWR is different of TR.

KEY WORDS: kinematics, deep water running, treadmill running, middle-distance.

INTRODUCTION: DWR has become an attractive training method, especially during recovery from musculoskeletal injuries of the legs. Proponents of DWR suggest that this modality can be used to maintain aerobic fitness, but without the orthopedic trauma associated with on-land running. Coaches are also incorporating DWR as part of their regular training regimen even in the non-injuried runner (Town & Bradley, 1990). One reason why DWR has increased in popularity over the years is the concept that the running action during DWR is similar to TR while eliminating the repetitive high impact forces (Mayo, 2000). Yu *et al.* (1994) affirm that to understand better the alterations that happen in the ground and in water locomotion is necessary to study the biomechanical parameters of two activities. The purpose of this study was to determine if the DWR is similar to TR, in this way, certain analyses were carried on kinematic parameters of stride lenght (SL), stride frequency (SF), stride time (ST), horizontal velocity (HV), and temporal relations of thigh and shank limbs during DWR and TR of five male middle-distance runners experienced in the two environments.

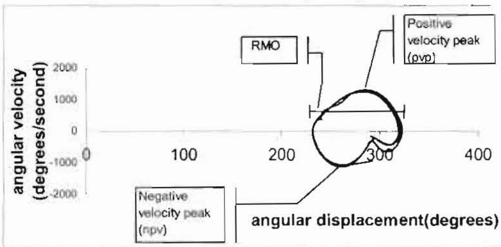
METHODS: Five Brazilian male middle-distance runners of national level (age 17.8 ± 2.6 years, mass 66.9 ± 2.8 kg and height 1.74 ± 0.05 m) participated in this study. The runners were requested to run in subjective intensities of regenerative effort, long aerobic, race of 5/10km, race of 400/800m and race of 100/200m on treadmill and in water. The running kinematics were registered with a video camera. The 2-D filming was obtained with a camera (Punix F4, 60 Hz) that was placed on the runner side, 3.5 m and 6.8 m distant from the treadmill and the water, respectively, linked to a video system (Peak Performance vs 5.3). Reflexive tape was used to obtain a better contrast of the hip, knee and ankle joint centers. The calibration in both the experimental conditions was executed each test started to decrease the distortion of the image in underwater analysis because of the refraction at the air-glass-water barrier. The treadmill used was of Quinton mark, with superfice of 2.0 m lenght and 0.7 m wide. The DWR tests were conduced in environment temperature varying from 19° C to 22° C. The data of DWR were collected in a swimming pool of 25x16 m, with 2m in depth, which the subjetcs used a float belt. The recording was across the lateral pool window. The deep water test was done in water temperature ranged between 29.5° C and 30.5° C.

Table 1. Protocol developed by Wilder & Brennan (1993) and modified in this study.

Time	Intensities	
10 min	Warm-up	Regenerative
2 min	very light	Regenerative – light jogging
2 min	Light	Long aerobic - long steady run
2 min	Moderate	5km\10km - 5- to 10-km race
1 min	Hard	400m\800m - 400- to 800-m track interval
30 sec	very hard	100m\200m - sprinting 100-200 m
3 min	Recovery	Regenerative

Between each intensity there was an active break (regenerative) of 30 sec.-1 min.

The Wilder & Brennan's protocol with a subjective effort percetion scale was chosen because of the specific intensity of each runner. For instance, intensity 3 - moderate - pace of 5 km\10 km.



Mavp = Mean of angular velocity peaks

pvp = positive velocity peak

nvp = negative velocity peak

Mavp = (pvp + nvp) / 2

ROM = Mean of angular amplitude

Figure 1. ROM, positive velocity peak (pvp) and negative velocity peak (nvp), in three continuous steps (Peyré Tartaruga et al., 2000).

Data processing: The video recordings were manually digitized using a Peak Performance Measurement System (Peak Performance Technologies, Denver, CO, USA). All the curves were filtered with a Butterworth filter and a cut-off of 11Hz. Besides the kinematic variables of ROM and angular velocity acquired through phase portraits, we also assess the following kinematic variables: SF, SL, ST e HV. To determine these variables the horizontal velocity (m/sec) in TR was considered, it was given by digital dial of the treadmill, and to horizontal velocity in DWR the mean horizontal velocity of anatomical hip point on three stride cicles was considered.

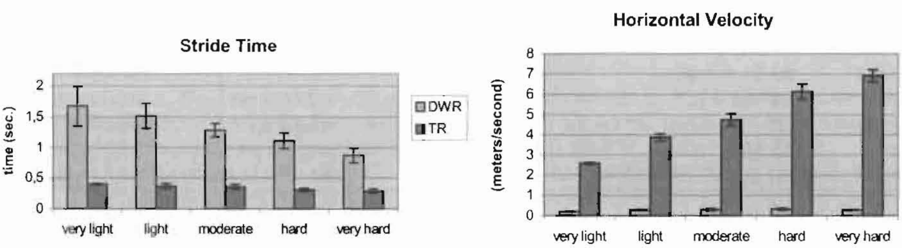


Figure 2. Mean values of HV (m/sec) and ST (sec) on five effort intesities between DWR and TR.

For each subject, the mean values of the kinematic variables were calculated from three continuous strides, the medium values of all the kinematic variables. All the 5 individuals' mean values were divided by intensity of effort. Student's test-t paired was performed ($p<0.05$) for each effort intensities between the environments in the statistical package SPSS (vs 8).

RESULTS AND DISCUSSION: For the SF, in DWR, there was an increase according to the increase of effort intensity, while SL tended to decrease from light intensity (figure 3), with increase of intensity. In spite of this increase, the HV showed a light increase until the 400/800m with a decrease in very hard intensity of 100/200m, it makes us believe that the increase of effort intensity in DWR is mainly due to the increase of SF. In the comparison with TR values, we can state that in both environments the SF showed the same behaviour, it increased according to the addition of effort intensity, the HV increased with the elevation of effort in TR, as expected, however, in DWR there was a decrease of HV, this was caused by the behaviour SL. This trend in SL coincided with the decrease of shank ROM value (table 2), it makes us believe that increasing the angular limbs velocity has been necessary to decrease the thigh and shank ROM in this exercise way (DWR).

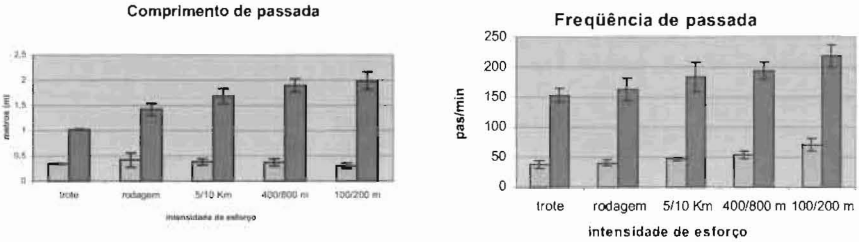


Figure 3. Mean Values of SL, SF in the five effort intensities between DWR and TR.

Comparing the analysis of the two exercise ways in figures 2 and 3, it showed statistical significant differences (*p*<0,05) in all analysed variables. The kinematic variables of SF, SL and HV in DWR obtained less outcomes than the TR, while the ST of DWR was bigger than the TR, this decrease in movement velocity is also found in angular velocities in shank and thigh limbs, this behaviour is a result of the greater environment liquid viscousity in relation to the land environment. To Mayo (2000), there are little diferences between the on-land running and DWR mechanics; however, the outcome presents consistents differences, mainly in the angular velocity of lower limbs (table 2) and general kinematic variables (figure 2 and 3).

Table 2. ROM (Mean and Standard deviation) whitin Three Steps on TR and DWR in the Five Intensities of Effort. (n = 5, * p<0.05).

INTENSITY	ROM (degrees)					
	SHANK			THIGH		
	TR		DWR	TR		DWR
very light	89.51 ± 6.96		110.95 ± 22.54	50.16 ± 3.22	*	87.07 ± 17.71
light	117.52 ± 8.7		106.84 ± 21.44	64.16 ± 5.85	*	91.06 ± 12.98
moderate	137.73 ± 5.83	*	100.18 ± 17.1	78.09 ± 7.91	*	91.04 ± 12.08
hard	142.13 ± 16.05	*	97.78 ± 20.71	81.01 ± 11.52	*	96.21 ± 10.17
very hard	137.7 ± 20.09	*	93.8 ± 24.56	84.18 ± 9.49		87.51 ± 14.63

Despite the fact that the kinematic variability of DWR is greater than in TR, it was not big enough not to be able to determine determine a movement pattern of DWR, as stated Griffin (1993). The effect of float in lower limbs (ankle), used by the referred author, must have been the reason of the big variability in your results, while we choose for use a float belt. It is likely that this little variability has been the effect of placing the float the nearest center of mass. The outcomes of comparisons of angular velocity and ROM of shank and thigh between TR and DWR show statistical differences in angular velocity and ROM of lower limbs in nearly all the running intensities (table 2 and 3), with exception of the shank ROM in regenerative and long aerobic intensities, and the thigh ROM in subjective effort 100/200m (table 2), no statistical differences were observed (p>0.05).

Table 3. Angular Velocity (Mean and Standard deviation) whitin Three Steps on TR and DWR in the Five Intensities of Effort. (n = 5, * p<0.05).

INTENSITY	Angular Velocity (degrees/sec.)					
	SHANK			THIGH		
	TR		DWR	TR		DWR
very light	931.59 ± 126.87	*	209.72 ± 25.95	609.83 ± 159.47	*	175.22 ± 31.65
light	1065.75 ± 28.03	*	251.62 ± 116.16	764.26 ± 55.14	*	233.41 ± 92.86
moderate	1244.5 ± 104.69	*	280.98 ± 138.17	968.69 ± 128.12	*	260.13 ± 102.96
hard	1427.72 ± 102.05	*	340.79 ± 165.48	1153.1 ± 41.9	*	329.54 ± 112.18
very hard	1623.37 ± 207.96	*	472.99 ± 214.32	1200.87 ± 121.54	*	447.36 ± 135.69

In 5/10 Km, 400/800 m, and 100/200 m rythms, the angular shank ROM was bigger in TR than DWR, however, thigh ROM was greater in DWR than TR in regenerative, long aerobic, 5/10 km, and 400/800m subjective efforts intensities (table 2). The mechanism from this increase of limb thigh ROM, may be due to DWR, has not the support phase of on-land running. Frangolias & Rhodes (1996) indicate that in DWR a improvement in joint hip flexibility is possible. The angular thigh ROM in DWR was bigger than TR in regenerative, long aerobic, 5/10km, and 400/800m intensities, we indicate flexibility active work in muscles flexors and extensors hip groups in this effort intensities. The shank and thigh angular velocities in TR were bigger than in DWR, it can observe that angular velocity behavior of analysed lower limbs were increasing according to the increase of effort intensity in both of environment situations (table 3). It also observed a bigger variability between the subjects in DWR than TR, it was determined from standard deviation showed in table 2 and 3.

CONCLUSION: The kinematics of DWR is different to kinematics of TR. The data of the present investigation demonstrated that DWR may work as a stretching training for the hip in the intensities of very light, light, moderate and hard. The angular velocities for DWR were greater than values presented for TR. Future studies on the electromyography of DWR are required to take into consideration the influence of muscle activation in this mode of exercise.

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