COMPARISON OF LOWER LIMB KINEMATICS OF MIDDLE-DISTANCE RUNNERS DURING TREADMILL RUNNING

Leonardo Alexandre Peyre Tartaruga, Ana Carolina Chaves Larronda, Jefferson Fagundes Loss and Luiz Fernando Martins Kruel
Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil

The purpose of this study was to compare angular kinematic parameters (angular velocity and range of motion) of lower limb among subjective effort intensities, through phase portrait analysis, during treadmill running. Seven male middle-distance runners of national level were requested to run in intensities of regenerative effort, long aerobic, 5/10km, 400/800m and 100/200m. Three complete running steps were recorded. Two-dimensional analysis methods were employed to analyse the lower limb movement. The results revealed that the shank and thigh angular range of motion and angular velocity increased with effort, except for in the 100/200m intensity, where the values of range of motion were not different from the 400/800m intensity. Phase portraits analysis is an interesting tool for the evaluation of the running technique.

KEY WORDS: running, middle-distance, kinematics, phase portraits, lower limb

INTRODUCTION: Investigations concerning individual running styles and the movement pattern of runnning were performed in different speeds. However the great majority of studies analyze step cycle, for instance, the touch-down or take-off and its several kinematic variables (Wank, Frick & Schimidtbleicher, 1998; Mayne, 1994). Other areas have been using the phase portrait analysis, for kinematic evaluation of corporal segments. A phase portrait is a representation of movement of a limb using position and velocity. The position of the segment is represented in the X axis and its velocity in the Y axis. Any point in the graph represents that segment in that instant in time (Clark, Truly & Phillips, 1990).
Analyses in phase portrait have been used frequently for Coordination and Motor Control studies (Clark, Truly & Phillips, 1990; Clark & Phillips, 1991; Thelen, Kelso & Fogel, 1987), as well as in studies for determination and evaluation of physical and mental pathologies (Winstein & Garfinkel, 1989). In the athletics, more specifically in middle-distance and distance, every time better results have been looked for races, through the progress in the organization of the training and also in the introduction of new evaluation techniques.
The purpose of this study was to determine and compare the lower limb kinematic parameters (angular velocity and range of motion - ROM) in different effort intensities, throught phase portrait analisys during treadmill running.

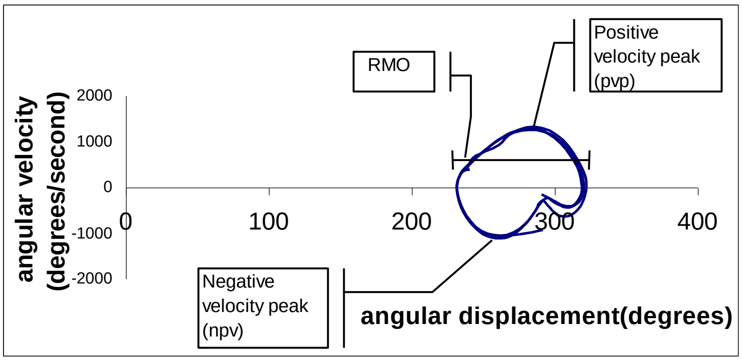
METHODS: Seven Brazilian male middle-distance runners of national level (age 17.8 ± 2.6 years, mass 66.5 ± 2.5 kg and height 1.77 ± 0.05 m) participated in this study. The runners were requested to run in subjective intensities of regenerative effort, long aerobic, race of 5/10km, race of 400/800m and race of 100/200m. The running kinematics were registered with a video camera. The 2-D filming was obtained with a camera (Punix F4, 60 frames per second) that was placed on the runner side, 3.5 m distant from the treadmill, 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. All the subjects were asked to perform the protocol presented in Table 1.
The execution of the filming was after the moments of stabilization of the runner in a certain velocity. This velocity was determined vocally or for gesture by the runner himself starting from his subjective perception to the effort.

Table 1 Protocol Developed by Wilder & Brennan (1993) and Modified in this Study

Time	Intensities
10 min	Warm-up (6.5 km/h)
2 min	Regenerative - very light or light jogging
2 min	Long aerobic - light or long steady run
2 min	5km\10km - moderate or 5- to 10-km race
1 min	400m\800m - hard or 400- to 800-m track interval
30 sec	100m\200m - very hard or sprinting 100-200 m
3 min	Recovery (6.5 km/h)

Between each intensity there was an active break (vel=6.5 km/h) of 30 sec.-1 min.

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



Mean of angular velocity peaks = **<u>Mavp</u>**

positive velocity peak = **<u>pvp</u>**

negative velocity peak = **<u>nvp</u>**

Mavp = (pvp + nvp) / 2

Figure 1 - ROM, positive velocity peak (pvp) and negative velocity peak (nvp), in three continuous steps.

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. After the coordinates and parameters calculations, the phase graphs were obtained. The used statistics was a descriptive type. Starting from the phase portraits, we placed the data of angular velocity and ROM in the statistical package SPSS (vs 8.0) for the determination and comparison among the different intensities of effort. Besides the quantitative analysis, we made a qualitative analysis concerning the area of the phase portraits in the different subjective effort intensities.
For each subject, the mean values of the angular variables were calculated from three continuous steps, the medium values of all the angular variables. All the 7 individuals' mean values were divided by intensity of effort. Each of the angular parameters was correlated to horizontal speed, to verify the dependence relationship among the variables (Pearson's correlation coefficient, $p<0.05$). One-way analysis of variance was performed, with a tukey-b post-hoc test ($p <0.05$) for each variable among the different effort intensities.

RESULTS AND DISCUSSION: The correlation coefficients between horizontal velocity and angular velocity of shank and thigh were 0.9062 and 0.9137 respectively, while the correlation coefficients between horizontal velocity and ROM in shank and thigh were 0.7900 and 0.8786, respectively. All the correlations obtained a significant index equal to or smaller than 0.0001. For the ROM (Figure 2), in both segments, there was an increase, according to the increase of effort intensity, with the exception for the 100\200m intensity of the leg segment, where statistical differences were not observed, according to Table 2. Also for ROM, we could observe, in both analyzed segments, statistical differences between the regenerative and long aerobic intensities, and between the long aerobic and pace of 5\10Km intensities, and this last intensity didn't show statistical differences from the 400\800m and 100\200m intensities.

Table 2 **Kinematic Parameters (Mean and Standard deviation) within Three Steps of Running on Treadmill in the Five Intensities of Effort. Different Letters Demonstrate Statistical Differences (n=7, p <0.05)**

	AAT (deg.)	AAS (deg.)	AVT (deg./sec.)	AVS (deg./sec.)
Regenerative	52.4 ± 5.4 a	93.0 ± 9.4 a	627.9 ± 142.2 a	936.4 ± 104.2 a
Long aerobic	64.9 ± 5.0 b	118.5 ± 7.3 b	783.4 ± 65.5 b	1078.2 ± 35.6 ab
5km\10km	77.6 ± 7.7 c	134.2 ± 7.8 c	958.2 ± 114.5 c	1222.6 ± 103 b
400\800m	81.9 ± 9.9 c	140.0 ± 14.3 c	1161.3 ± 41.8 d	1409 ± 112.2 c
100m\200m	84.8 ± 8.3 c	139.6 ± 17.1 c	1223.9 ± 106.8 d	1625.8 ± 172.6 d

Note: AAT = ROM of thigh; AAS = ROM of shank; AVT = angular velocity of thigh; AVS = angular velocity of shank.

In the angular velocity of the thigh (Table 2), statistical differences were verified among almost all the intensities, except for the intensities of 400\800m and 100\200m, in which statistical differences were not found. For the shank, the effort intensities that did not show differences in the angular velocity were the regenerative and long aerobic, and the long aerobic and pace of 5\10km intensities, respectively.

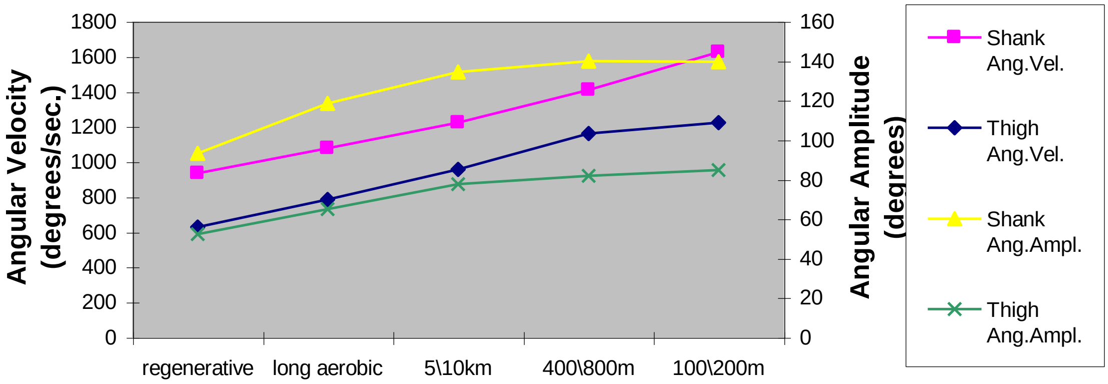


Figure 2 - Variation of the kinematic parameters in different running intensities.

The qualitative analysis of the phase portrait area revealed differences among the five effort intensities. An increase in the area of the phase portrait was observed, as it increased with the effort intensity. The same happened with the mean angular velocity, in the shank and thigh segments.

In the kinemaic variables comparison, between the shank and thigh segments, for the angular velocity and for the ROM, the results were larger in the shank segment.

According to the ROM data of the shank segment the results agree with Baeta & Mckenzie data (1989). For the thigh ROM value, in the 100\200m intensity our results of 84.8 degrees are different from the 92.2 degrees found by Mayne in a group of Spanish runners. This difference probably happened because the work of Mayne was performed in the track, while we chose a treadmill running, and one of the changes in the running patterns between the ground and the treadmill running is the decrease of the step length, and, consequently, a smaller ROM of the thigh (Elliott & Blanksby, 1976; Nigg, De Boer & Fischer 1995; Wank, Frick & Schimidtbleicher, 1998).

CONCLUSION: The purpose of this study was to determine and to compare the kinematic angular parameters velocity and ROM of lower limbs in different effort intensities through phase portraits analisys. The phase portraits were shown, in their compositions general, fully constant, and proved through the quantitative analysis, for the values of angular velocity and ROM of the shank and thigh segments. The thigh obtained a variation among the subjects, smaller in relation to the leg values.

We suggest that for future studies of cyclical sport movements, more specific correlations between total energy expense of the organism and area of the phase portraits in the corporal segments should take place. Finally, we would like to point out the real possibilities of phase portraits graphs as a valuable instrument in the evaluation of the running technique in different effort intensities.

REFERENCES:

Baeta, A., & Mckenzie, J. (1989). Middle and Long Distance Training. In: GAMBETTA, V. (Ed). *Track and Field Coaching.* T.A.C. USA.

Clark, J.E., & Phillips, S.J. (1991). Revision - a longitudinal study of intralimb coordination in the first year of independent walking: a dynamical systems analysis. *Annual Conference of the North American Society for the Psychology of Sport and Physical Activity*. Asilomar, CA.

Clark, J.E. Truely, T.L., & Phillips, S.J. (1990). On the development of walking as a limit cycle system. In : THELEN, E & SMITH, L (Eds.) *Dynamical systems in development: application*. Cambridge, MA: MIT press.

Elliott, B.C., & Blanksby, B.A. (1976). A Cinematographic Analysis of Overground and Treadmill Running by Males and Females. *Medicine and Science in Sports and Exercise,* **8**, 84-87.

Mayne, C.T.I. (1994). Estudio Biomecánico de la Técnica de Carrera Lanzada en las Pruebas de Velocidad Femenina. *Apunts de Medicina Deportiva*, **31**, pp 129-140.

Nigg, B.M., De Boer, R.W., & Fischer, F. A (1995). Kinematic Comparison of Overground and Treadmill Running. *Medicine and Science in Sports and Exercise.* **27**, 98-115.

Thelen, E. Kelso, J.A.S., & Fogel, A. (1987). Self-Organizing Systems and Infant Motor Development*. Developmental Rewiew*. **7**, 39-65.

Wank, V. Frick, U., & SchmidtbleiIcher, D. (1998). Kinematics and Electromiography of Lower Limb Muscles in Overground and Treadmill Running. *International Journal of Sports Medicine*, **19**, 455-461.

Wilder, R.P., & Brennan, D.K. (1993). Phisiological Responses to Deep Water Running in Athletes. *Sports Medicine*, **16** (6): 374-380.

Winstein, C.J., & Garfinkel, A.. (1989). Qualitative Dynamics of Disordered Human Locomotion: A Preliminary Investigation. *Journal of Motor Behavior*, **21**(4), 373-391.

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