# COMPARISON IN LOWER LIMB KINEMATICS AFFECTING RUNNING ECONOMY OF TRAINED AND UNTRAINED RUNNERS

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This study compared trained and untrained runners to explore factors affecting running economy(RE). Trained male and untrained male distance runners participated in this study. The trained participants ran for 4 min at 6 different constant speeds, while the untrained participants ran at 4 different constant speeds on a level treadmill. During the test, respiratory variables associated with RE were continuously measured using an expiration gas analysis system. Stride parameters such as step length and frequency, as well as phase time and joint kinematics such as joint angles, range of motion, and joint angular velocity of the lower limb joints were calculated from marker coordinates. There was a significant difference in RE between trained and untrained runners. Some stride characteristics significantly affected both training and RE.

**KEY WORDS:** stride characteristics, lower limb motion, treadmill.

**INTRODUCTION:** Running economy (RE) is commonly defined as the energy expenditure required at a given submaximal velocity. RE is strongly correlated to distance running performance. Researchers have recently investigated biomechanical factors affecting RE.

Ogueta-Alday et al. (2014) described better RE in rearfoot strikers. By contrast, Santos-Concejero et al. (2014) described better RE in midfoot strikers. Thus, recent findings are inconsistent. One of the major reasons for this inconsistency seems that the previous studies did not take into account differences in runner performance levels.

The purpose of this study was to explore the factors determining RE by comparing trained and untrained runners.

**METHODS:** Twelve trained (age 21.8±1.9 yrs; height 172.2±4.2 cm; mass 62.0±4.5 kg; 5,000 m time 16’ 20” 11±48”) and ten untrained male distance runners (age 22.1±1.4 yrs; height 173.2±5.0 cm; mass 63.9±10.0 kg) participated in this study. The trained participants ran for 4 min at six different constant speeds (180, 210, 240, 270, 300, and 330 m/min), while the untrained participants ran at four different constant speeds (150, 180, 210, and 240 m/min) on a level treadmill. Sufficient rest times (over 7 min) were provided between each set.

During the test, respiratory variables associated with RE were continuously measured using an expiration gas analysis system (VO2000, S&ME Inc.). Kinematic data were recorded at 250 Hz with 10 cameras comprising an optical motion capture system (Optitrack S250e, Natural Point Inc., USA). The subjects were equipped with 12 retro-reflective markers on the head of fifth metatarsal, heel, lateral malleolus, lateral epicondyle, and great trochanter of both sides and the cervical spine and suprasternale. Stride parameters such as step length, step frequency, and phase time; and joint kinematics such as joint angles, range of motion, and joint angular velocity of the lower limb joints were calculated from these marker coordinates.

2D kinematic data were analyzed for 30 running cycles at each running speed, and the mean of 30 running cycles was considered the representative value at each speed. Foot strikes and toe-off positions of the right foot were determined from the obtained kinematic data. We divided a running cycle into six phases (brake, propulsion, after-off, forward swing first [Fwd. Swing 1st], forward swing second [Fwd. Swing 2nd], and pre-on) according to the relative position of the metatarsal to the great trochanter.

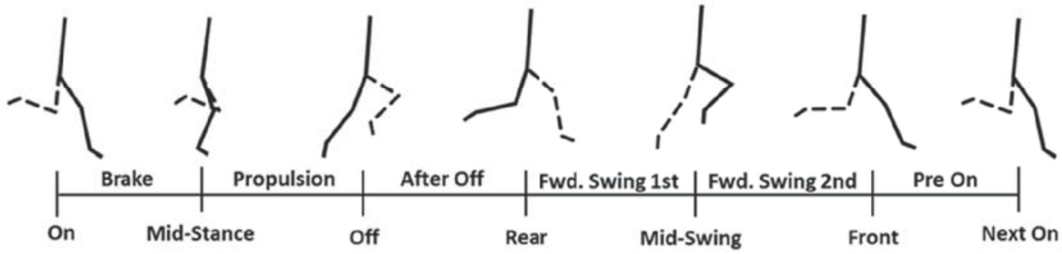


**Figure 1:** Six phases of a single running cycle.

Energy expenditure (EE) [J/kg/min] was calculated from the following equation (Kyrolainen et al., 2001) using the oxygen uptake ($VO_2$) [mL/kg/min] and respiratory exchange ratio (RER).

$$EE = (5{,}000 \times RER + 16{,}102) \times VO_2 / 1000 \quad \cdots (1)$$

A regression line between the running speed and EE was determined using the data below 90% of the $VO_2$ peak. The slope of the regression line was defined as the RE [J/kg/m]. In this definition, smaller RE values correspond to more economical performance.
To examine differences in RE and performance between trained and untrained runners, independent t-tests were performed. To examine differences in lower limb kinematics between trained and untrained runners based on the influence of running speed, analysis of covariance (ANCOVA) was performed using running speed as a covariate.

**RESULTS AND DISCUSSION:** There was a significant difference in RE between trained and untrained runners.
The stride characteristics that both significantly affected training and were significantly correlated with RE in the current study included percent touch-down distance (%TDD), percent brake-phase time (%BRT), percent first forward swing phase time (%SW1T), percent pre-on phase time (%POT), vertical displacement of the center of gravity from foot strike to the lowest point (h1), and vertical displacement of the center of gravity from toe off to the highest point (h3).
%TDD values were significantly shorter in trained runners than in untrained runners, regardless of running speed. Furthermore, %TDD was positively correlated with RE.
Figure 2 shows changes in %BRT with increasing running speed. These values were significantly shorter in trained runners than in untrained runners, regardless of running speed. In this phase, body weight is received and braking force is applied. Furthermore, %BRT was positively correlated with RE. From these observations, trained runners appear to have more economical performance than untrained runners, with a reduced %BRT.

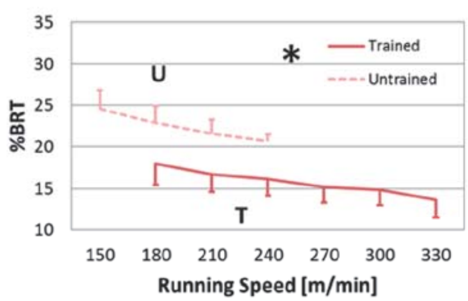


**Figure 2: Change in %BRT with increasing running speed.**

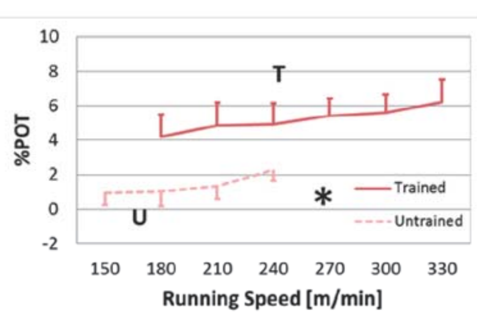


**Figure 3: Change in %POT with increasing running speed.**

%SW1T values were significantly longer in trained runners than in untrained runners, regardless of running speed. Furthermore, %SW1T was negatively correlated with RE. Figure 3 shows changes in %POT with increasing running speed. These values were significantly longer in trained runners than in untrained runners, regardless of running speed. In this phase, runners extend the hip joint to swing their free leg back. Lengthening this phase time helps to increase the velocity of the swing back. Increased swing back velocity leads to decreased braking at foot-strike.
h1 values were significantly smaller for trained runners than for untrained runners, regardless of running speed. h1 was positively correlated with RE. In addition, range of motion of the hip joint, the knee joint and the ankle joint in stance phase were smaller for trained runners than for untrained runners. These findings suggest that improved RE in trained runners was due to decreased h1 with smaller range of motion of these joints.
Figure 4 shows changes in h3 with increasing running speed. The values were significantly larger for trained runners than for untrained runners, regardless of running speed. In addition, there was a high positive correlation between h3 and airborne distance. These findings suggest that improved RE in trained runners was due to increased h3 with shorter stance phase time.

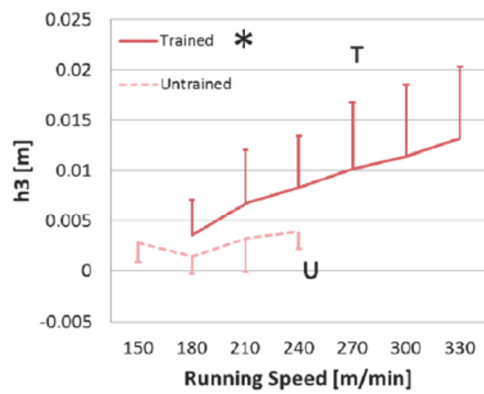


**Figure 4: Change in h3 with increasing running speed.**

**CONCLUSION:** We calculated the kinematics of the lower limb while running in order to examine the effect of training, and assessed the relationship between kinematics and RE. The results of the present study demonstrated that some stride characteristics may affect RE.

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