INFLUENCE OF SLOPE ON SUBTALAR PRONATION IN SUBMAXIMAL RUNNING PERFORMANCE

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ABSTRACT

Objective: To investigate the slope influence on the maximal subtalar pronation in submaximal running speeds. Methods: Sixteen endurance runners participated of a running economy (RE) test in a treadmill with different slopes (+1%, +5%, +10%, +15%). For each slope a 4-minute run was performed with no rest break for the purpose of measuring the magnitude of kinematic variables by means of a high frequency video camera positioned in a frontal-posterior plane of the individual. Results: No significant differences were verified in maximal subtalar pronation between legs and between the slopes adopted, showing that changes of running technique due to modifications of slope aren't enough to modify the behavior of maximum subtalar pronation. Conclusion: The subtalar pronation is independent of slope, which may be influenced by other intervening variables. ***Level of Evidence II, Diagnostic Study.***

Keywords: Pronation. Subtalar joint. Locomotion. Running.

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INTRODUCTION

During recent decades, the study of human gait has been spread considerably among the various sports research centers.[1] Many surveys have been developed aiming to study the relationship between physical activity and injuries, particularly those related to running.[2,3] Studies relating the behavior of the subtalar joint angle, specifically subtalar pronation, and the type of footwear used for running, have achieved significant importance in the search for a better understanding of injuries involving the hip, knee, ankle and foot.[2]

Subtalar pronation consists of an impact absorbing mechanism, which acts in combination with other body mechanisms, decreasing the tensions on some articular structures, with an adequate level of impact, without provoking micro-traumatisms. However pronation becomes pathological when it exceeds its physiological articular range of motion, in which this state is known as hyperpronation, considered a maximum value of subtalar pronation above 12 degrees, approximately.[4,5] It is widely published in literature that pronation of the subtalar joint is a result of an association of movements, namely foot eversion, dorsiflexion and abduction, (Figure 1) which occur in the frontal, sagittal and transversal planes.[6,7]

Maximum subtalar pronation, generally reached between 20 and 40% of the stance phase period, (Figure 2) is mainly influenced by the linear speed of running, by intensity of effort, by muscle imbalance and/or ligament laxity and by the running technique imposed by the runner.[3,5]

Several studies have associated maximum subtalar pronation with running linear speed. However, some studies have associated the behavior of this variable, mainly, to the intensity of physical effort.[8] According to Tartaruga et al.[5] maximum subtalar pronation presents strong correlations with running economy (ECO) and, consequently, with intensity of effort. ECO is taken to mean the submaximal oxygen consumption at a given submaximal running speed.[1,9] Tartaruga et al.[5] verified that as the linear running speed increases (14 kmh^{-1} to 16 kmh^{-1} in men and 11 kmh^{-1} to 13 kmh^{-1} in women - different speeds, but similar intensities between men and women referring to the maximal oxygen consumption - VO_{2max}) the maximum subtalar pronation increased significantly from 6.79 to 9.69 degrees in the men and from 5.87 to 9.44 degrees in the women, i.e., similar increases for both sexes.

In several situations in daily life, human beings come across access routes on an inclined plane, such as ramps, upward and downward slopes of various types. The musculoskeletal system is able to detect and promptly respond to surface alterations, by means of changes in the activation time and in the magnitude of the neuromuscular activity. To maintain body balance, trunk, pelvic girdle and lower limbs constantly adapt through

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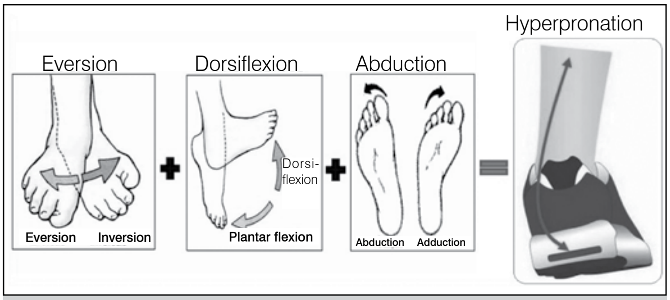

Figure 1. Excessive pronation of subtalar joint.

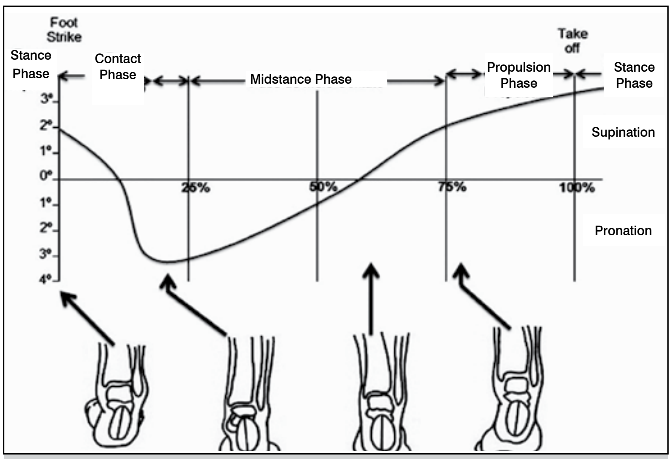

Figure 2. Movement of posterior part of the foot during the stance phase.

several mechanisms, including forward projection of the center of gravity during the ascent. By means of studies that evaluated the locomotive adaptations that occur in the transition from the horizontal plane to the inclined plane, it is known that several postural alterations are observed, such as increased flexion of the hip, knee and ankle joints,[3] although Scholz et al.[10] attribute the postural changes and ECO to matters related to neuromuscular adaptations. On the inclined plane it is necessary to decrease the shock absorption period and to increase the propulsion time. For this purpose, there is an increase in the strength application time in the propulsion phase, characterized by the increased electromyographic activity of the medial gastrocnemius and tibialis anterior muscles, which when coactivated, promote greater propulsion and, probably, changes in the biomechanical behavior of the subtalar joint.[11]

In spite of the studies developed with the objective of investigating the relationship between subtalar pronation and gait speed, as well as the relationship between gait on an inclined plane and musculoskeletal injuries, no studies have been observed that investigate the influence of the slope on the behavior of the subtalar joint. Therefore, the goal was to analyze the influence of the slope on maximum subtalar pronation of endurance runners.

MATERIAL AND METHOD

The sample was composed of 16 runners, with experience in medium- and long-distance running, selected in a non-random manner, as volunteers, exempt from physical problems and from pharmacological treatment. The sample number, defined on a basis of the studies of Tartaruga et al.[12] and Williams & Cavanagh,[13] was determined through the Computer Programs for Epidemiologic Analyses (PEPI) program, adopting a significance level of 0.05 and a power of 90%. The study was approved by the Ethics Committee in Research (No. 415238) and is in accordance with the 1995 Declaration of Helsinki.

A pair of scales and stadiometer (WELMY-110, Santa Bárbara d'Oeste/SP, Brazil), a skinfold caliper (CESCORF-scientific, Porto Alegre/RS, Brazil), a tape measure (STARRETT-510, Itu/SP, Brazil), a treadmill (MOVEMENT-RT250, Pompéia/SP, Brazil) and a digital camcorder (CASIO-EXFH25, Tokyo, Japan) with sampling frequency of 240 Hz were used to gather data.

First of all the individuals completed the personal information form, underwent anamnesis and signed the Informed Consent Form. After this body mass, stature, leg length and body fat percentage (%G) data were measured with a basis on the protocol adopted by Siri.[14] For these measurements, the individuals were barefoot and wore just a pair of shorts. The measurement of the leg length, taken on both legs, consisted of the corresponding distance between the greater trochanter of the femur and the ground. Individuals presenting differences of more than 1 centimeter between the legs were excluded from the study. All the measurements were taken by a Physical Education professional with experience in anthropometric evaluations.

The individuals were submitted to a test of maximum progressive effort in order to determine the VO_{2max}[15] for sample characterization purposes. This was followed a week later by an ECO test composed of four 4-minute runs on different slopes without any intervals between them. Four reflective points were affixed to each leg, (Figure 3) based on the protocols adopted by Ferrandis et al.[16] and Tartaruga et al.[3]

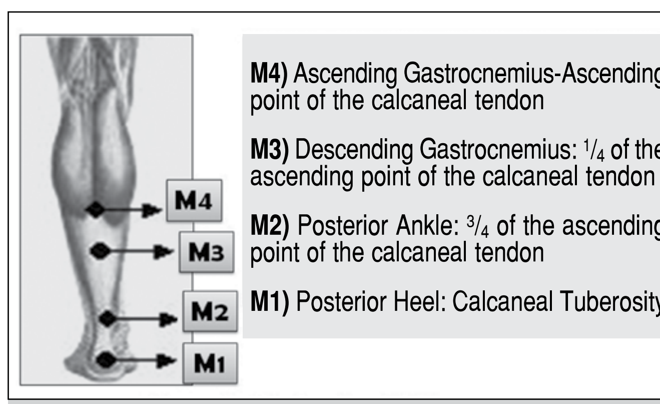

Figure 3. Anatomical points.

After the preparation phase, the treadmill was turned on and following a 3-minute warm-up (walk at comfortable speed), the speed was increased up to the optimal running speed, which was self-selected by each individual, and maintained for 4 minutes on each one of the slopes adopted in the study (+1%,+5%, +10%, +15%). All the individuals had experience running on a treadmill. In the last minute of each slope the subjects were filmed for 10 seconds using a digital camcorder positioned at a distance of 2 meters from the posterior frontal plane of the treadmill. (Figure 4)

All the runners were asked to use their own training shoes, with rubber soles and without cleats. Sports shoes and anti-prona-

Figure 4. Kinematics of the posterior frontal plan.

tion shoes were not allowed. For the data treatment three pace cycles were analyzed for each leg. The kinematic records were scanned manually and automatically using *Dvideo* software, and later used to determine the maximum angles of the subtalar joint through a routine developed in the *MATLAB* software.

The normality and homogeneity of the data were verified through the Shapiro-Wilk and Levene tests. As the results presented symmetrical behaviors, the descriptive analysis was carried out with mean and standard deviation and the Student's t-test was applied to dependent samples aiming to compare the mean values of the maximum subtalar pronation of both legs. The Analysis of Variance (VAS) and the Tukey B post-hoc test were adopted to compare the values between the slopes. A value of $\alpha < 0.05$ was adopted for all the statistical tests, while the statistical package used was the Statistical for Social Sciences Software - SPSS, version 15.0.

RESULTS

The results referring to the sample characterization are presented in Table 1.

Table 1. Characterization of the sample: mean, standard deviation (SD), minimum and maximum values of the variables age, body mass, stature, percentage of body fat and maximal oxygen consumption of 16 endurance runners.

Variables	Mean	SD	Minimum	Maximum
Age (years)	29.0	6.98	19.0	41.0
Body Mass (kg)	70.0	10.1	54.0	90.0
Stature (m)	1.71	0.06	1.62	1.82
Leg Length (m)	0.79	0.03	0.75	0.87
Body Fat (%)	14.6	3.15	11.5	23.2
VO_{2max}($mlO_2 \cdot kg^{-1} \cdot min^{-1}$)	52.0	4.92	42.3	58.4

N.B.: Maximal Oxygen Consumption (VO_{2max}).

There were no significant differences verified in the values of maximum pronation (MP) between the legs and between the slopes in both legs. (Figure 5)

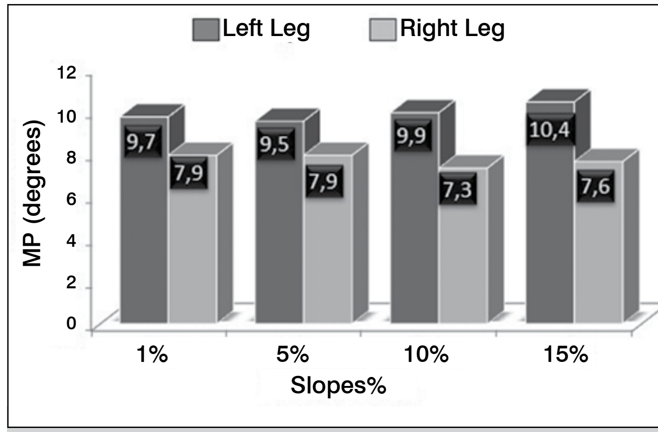

Figure 5. Comparison of the means of the values of maximum pronation between the left and right legs on +1%, +5%, +10% and +15% slopes.

DISCUSSION

There is a consensus in the literature that excessive subtalar pronation (hyperpronation) is one of the main causes of injury to the lower limbs, especially of runners, where this mechanism is constantly activated while running in order to minimize the damaging effects of the resulting force (normal force) arising from the foot's contact with the ground, as well as from the excessive internal rotation of the tibia. According to Snook[17] the internal rotation of the tibia, when repeated excessively, can result in hyperpronation of the subtalar joint and therefore in several osteoarticular complications.

The causes of lower limb pathologies also appear to result from the impact forces that overburden the pronation mechanism posing risks to the articular structures. Thus, when we observe hyperpronation of the subtalar joint it is very likely that this is also associated with a situation of strong impact, during the foot-ground contact phase, since pronation is understood as being a mechanism that attenuates the impact resulting from the foot's contact with the ground, and consequently offers osteoarticular protection.[18]

Impact forces appear to be more prominent in the foot's first contact with the ground, and are equivalent to two to three times the body weight in an average step frequency of 70 to 100 steps per minute.[5] The impact force is influenced by the running linear speed, by the movement technique, by the type of footwear used during locomotion and by the individual's plane of motion.[5,11,18]

As regards the slope, in our study this variable did not significantly influence the maximum subtalar pronation behavior and we did not observe any hyperpronation values. Consequently, it is believed that the slope, between +1% and +15%, besides not influencing the maximum subtalar pronation values, is probably incapable of altering the force of impact of the foot with the ground. Gottschall and Kram[11] verified that impact forces are influenced more by negative slope alterations due to greater use of elastic energy in comparison with positive slope alterations during locomotion. Moreover, in our study, the running speed was kept constant in a comfortable situation, which was probably not sufficient to result in muscle fatigue, and consequently, in changes in the articular behavior.

Many authors attribute the changes in the maximum subtalar pronation values mainly to the running technique.[9] Ortega et al.,[19] when comparing runners and walkers, find differences in the maximum values of subtalar pronation, where the group of walkers presented greater pronation (16.27 degrees in the right leg and 18.60 degrees in the left leg) than the runners (9.73 degrees in the right leg and 10.13 in the left leg), even though the walkers presented lower locomotion speeds than the runners. The authors attribute this interesting finding to a better running technique among the runners. Tartaruga et al.[5] verified that the maximum subtalar pronation increased significantly, from the speed of 14 $km.h^{-1}$ to 16 $km.h^{-1}$ (6.79 $\pm$ 4.01 degrees to 9.69 $\pm$ 3.14 degrees) in a group of men, as also occurred in a group of women, from the speed of 11 $km.h^{-1}$ to 13 $km.h^{-1}$ (5.87 $\pm$ 4.66 degrees to 9.44 $\pm$ 5.15 degrees). The speeds of 11 and 14 $km.h^{1}$ and 13 and 16 $km.h^{-1}$ corresponded to 70 and 75% of the VO_{2max} speed, respectively, for both sexes. These results demonstrate the importance of intensity of effort in the behavior of maximum subtalar pronation, as already demonstrated by Gheluwe and Madsen.[8]

In the same manner, authors have pointed out the importance of physical conditioning and of professional experience as variables allied with a good running technique and, consequently, with a lower probability of developing subtalar hyperpronation.[12,13,20]

As regards the comparison between the maximum values of subtalar pronation of the right and left legs, no significant differences were found. The results obtained in our study are consistent with the findings of Tartaruga et al.[3] who did not find significant differences in the values of this variable either, determined methodologically in a different manner (using only 2 reference points). Our results also corroborate those of Wit et al.[18] whose technique to determine the maximum subtalar pronation was similar. However, although we have not verified significant differences in the maximum subtalar pronation between legs in our study, the left leg tended to present higher maximum subtalar pronation values than the right leg. According to Tartaruga et al.[12] this tendency may be related to a slight sideways tilt of the trunk, resulting from an imperceptible tilt existing on athletics tracks and to the continuous training without a change in movement direction.

CONCLUSION

The slope does not influence the behavior of the subtalar joint during submaximal running and consequently, the appearance of articular lesions arising from this variable. Subtalar pronation is probably dependent on other intervening variables such as running speed and, particularly, the intensity of the physical effort. Future studies relating maximum subtalar pronation to the total mechanical work and the efficiency of endurance runners are suggested for a better understanding of the causes of hyperpronation and, consequently, of the appearance of resulting lesions in the hip, knee and ankle.

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