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 evasion, dorsiflexion and abduction, (Figure 1) which occur in the 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.

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 evasion, dorsiflexion and abduction, (Figure 1) which occur in the 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.

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.

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 evasion, dorsiflexion and abduction, (Figure 1) which occur in the 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.

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:
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, although Scholz et al. 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, when coactivated, promote greater propulsion and, probably, changes in the biomechanical behavior of the subtalar joint.

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. and Williams & Cavanagh, 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. 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 VO2max 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. and Tartaruga et al.

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-prono-
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.

![Figure 4. Kinematics of the posterior frontal plan.](image)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29.0</td>
<td>6.98</td>
<td>19.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>70.0</td>
<td>10.1</td>
<td>54.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>1.71</td>
<td>0.06</td>
<td>1.62</td>
<td>1.82</td>
</tr>
<tr>
<td>Leg Length (m)</td>
<td>0.79</td>
<td>0.03</td>
<td>0.75</td>
<td>0.87</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>14.6</td>
<td>3.15</td>
<td>11.5</td>
<td>23.2</td>
</tr>
<tr>
<td>VO_2max (mL O_2 kg$^{-1}$ min$^{-1}$)</td>
<td>52.0</td>
<td>4.92</td>
<td>42.3</td>
<td>58.4</td>
</tr>
</tbody>
</table>

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, 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.

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. 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.

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 verified that impact forces are influenced more by negative slope alterations due to greater use of elastic energy in comparison with positive
of the VO2max speed, respectively, for both sexes. These results
9. Tartaruga MP, Brisswalter J, Peyre-Tartaruga LA, Avila AO, Alberton CL, Coertjens M, Ca-
8. Gheluwe BV, Madsen G. Frontal rearfoot kinematics in running prior to volitional
7. Munuera PV, Dominguez G, Palomo IC, Lafuente G. Effects of rearfoot-con-
6. Arangio GA, Phillippy DC, Xiao D, Gu WK, Salathe EP. Subtalar pronation-relationship to
4. Klingman RE, Liao SM, Hardin KM. The effect of subtalar joint posting on
1. Conley DL, Krahenbuhl GS. Running economy and distance running perfor-

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 subta-
lar pronation values mainly to the running technique.9 Ortega et al.,18 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 de-
grees 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 ± 4.01 degrees to 9.69 ±
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 ±
4.66 degrees to 9.44 ± 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\(_{2}\)max 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.6

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.5 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 run-
ners 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.

ACKNOWLEDGMENTS

The authors are grateful to Fundação Araucária for the financial
support provided to the survey.

REFERENCES

1. Conley DL, Krahenbuhl GS. Running economy and distance running perfor-
4. Klingman RE, Liao SM, Hardin KM. The effect of subtalar joint posting on
6. Arangio GA, Phillippy DC, Xiao D, Gu WK, Salathe EP. Subtalar pronation-relationship to
7. Munuera PV, Dominguez G, Palomo IC, Lafuente G. Effects of rearfoot-con-
8. Gheluwe BV, Madsen G. Frontal rearfoot kinematics in running prior to volitional
9. Tartaruga MP, Brisswalter J, Peyre-Tartaruga LA, Ávila AO, Alberton CL, Coertjens M, Ca-
11. Gottschall JS, Kram R. Ground reaction forces during downhill and uphill
13. Williams KR, Cavanagh PR. Relationship between distance running mecha-
16. Ferrandis R, García AC, Ramiro J, Hoyos JV, Vera P. Rearfoot motion and torsion
17. Ellestad MH, Allen W, Wan MC, Kemp GL. Maximal treadmill stress testing for
18. Gheluwe BV, Madsen G. Frontal rearfoot kinematics in running prior to volitional
19. Tartaruga MP, Brisswalter J, Peyre-Tartaruga LA, Ávila AO, Alberton CL, Coertjens M, Ca-
21. Conley DL, Krahenbuhl GS. Running economy and distance running perfor-