The effects of sand dune and hill running on lower limb kinematics and running speed in elite sprinters.

THE EFFECTS OF SAND DUNE AND HILL RUNNING ON LOWER LIMB KINEMATICS AND RUNNING SPEED IN ELITE SPRINTERS

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The purpose of this study was to examine the technical adaptations used by elite sprinters when running on sand dunes compared with running on a grass surface of similar gradient. Seven elite sprinters were videotaped while running at maximum effort up inclined sand and grass surfaces. Sagittal plane kinematic data were obtained using two video cameras placed on either side of the subjects. The video sequences were analysed using the Peak Motus. video analysis system. The results indicated that sand running caused reductions in running speed, stride rate, stride length and thigh range of motion. Ground contact time of the foot was increased and the relative timing of stride events was also disrupted while running on sand and this suggests a greater muscle loading effect compared with running on grass.

KEY WORDS: velocity, technique, running surface.

INTRODUCTION: Sand dune running is a common training method used by both sprinters and endurance athletes. The Australian athlete Herb Elliott and his coach Percy Cerutti are often credited with popularising the use of sand dune running as an effective training method. While much anecdotal evidence exists on the training benefits of running on sand, there is very little scientific literature that explains the role that sand running may play in training for sprint or power events. From an endurance perspective, the current published literature highlights that running on flat soft sand is 1.4 times more energy demanding than running of other flat surfaces such as grass (Pinnington and Dawson, 2001). No peer reviewed literature presently exists which supports the use of sand dune running for sprint/power athletes and no experimental studies have examined the technical adaptations that occur in running biomechanics as a result of running up sand dunes. The purpose of this study was to investigate and compare the effects on lower limb kinematics and running speed of maximal effort running on sand dunes with running on a grass hill of similar gradient.

METHODS:
Subjects: Seven sprint/power-based athletes (aged 26.2 ± 3.67 years, mass 71.4 ± 10.3kg, height 177.2 ± 9.7cm) volunteered to participate in this study. All athletes were national champions and/or record holders in their chosen event, and had competed either, at Senior International, World or Olympic level and were therefore deemed 'elite' performers. All subjects were in full training and injury free.
Subject preparation: Subjects wore dark coloured LycraÆË running tights and Circular markers (55mm diameter) were fixed to the athletes' right and left legs on the following positions: superior to the lateral malleolus of the ankle, inferior to the lateral head of the fibula, superior to the lateral condyle of the femur, inferior to the greater trochanter of the femur. These markers were used to facilitate video digitization.
Procedures: All athletes were required to perform five maximal effort sprint trials running up a sand dune (inclined at approximately 20o) and a grass hill (inclined at 18o). They were allowed a full recovery between trials. Subjects' sagittal plane motion was video taped while running up the hill by two Panasonic Digital Video cameras sampling at 50Hz, placed on either side of the subject. Two marker poles were inserted vertically into the ground/sand in the path of the runners to identify a measurement zone and facilitate scaling of the video data.
Video Analysis 2D kinematic analyses of the video sequences were carried out using the Peak MotusÆË video analysis system (Peak Performance Technologies Inc.). The video sequences were manually digitized at a frequency of 50Hz. The raw coordinate data was smoothed using a general cross-validated spline algorithm. From these data, the vertical displacement of the lower shank marker and the segment and joint angles of the thigh, shank and knee were

obtained. Average running velocity within the marked measurement zone was calculated from the smoothed coordinate data of the hip marker.

Data Analysis: The data were statistically analysed in SPSS 11.0, using General Linear Model, ANOVA with three repeated measures factors, namely, surface with two levels (sand and grass), side with two levels (right and left) and trials with five levels. The dependent variables were running velocity, stride rate, ground contact time, ratio of contact time to stride time, range of motion of the thigh and vertical displacement of the lower shank marker during ground contact.

RESULTS: Figure 1 shows the effect of grass and sand surfaces on average running velocity. The GLM ANOVA on these data indicates significant main effects for surface ($p < 0.001$) and trials ($p=0.002$). Figure 2 shows the effect of grass and sand surfaces on stride rates for right and left legs. These data indicate a significant main effect for surface ($p=0.001$) and a significant surface × trials interaction effect.

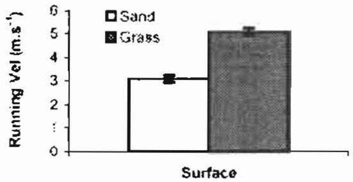

Figure 1: *Mean and SD of running velocity on sand and grass*

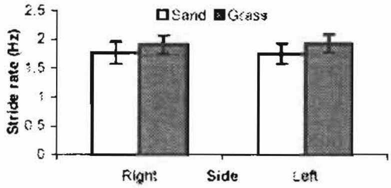

Figure 2: *Means and SDs for Stride Rates on sand and grass for right and left legs*

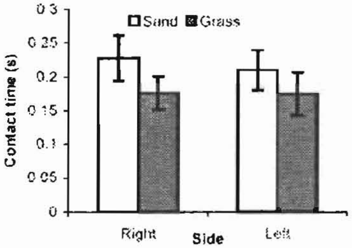

Figure 3: *Means and SDs for ground contact times on sand and grass for right and left legs*

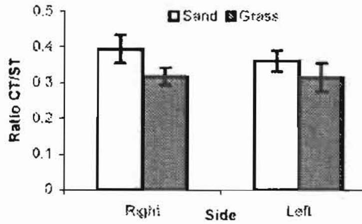

Figure 4: *Means and SDs for ground contact/stride time ratios on sand and grass for right and left legs*

Figure 3 demonstrates the effect of sand and grass surfaces on ground contact times. These data indicate significant main effects for surface ($p=0.004$) and side ($p=0.031$) and a significant surface × side interaction effect ($p=0.049$). Figure 4 shows the results of the analysis of contact time/stride time ratios for running on grass and sand surfaces. These data indicate a significant main effect for surface on the contact time/stride time ratios ($p<0.001$). Figure 5 shows the analysis of thigh ROM data for running on sand and grass surfaces. These data indicate a significant main effect for surface on the thigh ROM ($p=0.022$). Figure 6 shows the mean vertical displacement of the left lower shank marker during the ground contact period (expressed and a percentage). These data demonstrate a distinct lowering of the marker during the first half of the contact period. The magnitude of this drop is noticeably greater during sand running. However, the ANOVA on these data did not indicate significant main effect for surface ($p=0.104$).

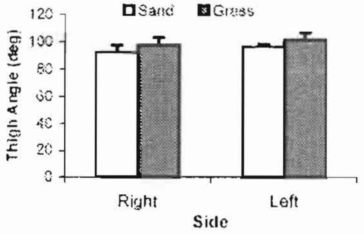

Figure 5: *Means and SD's for range of thigh motion for right and left thighs on sand and grass*

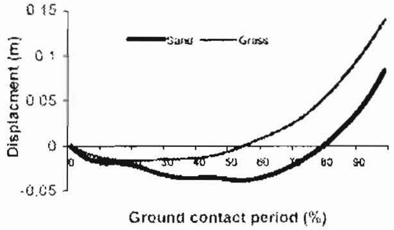

Figure 6: *Mean vertical displacement of lower shank marker during ground contact phase on sand and grass*

DISCUSSION: Inspection of the data in this study demonstrates that there were clear differences between running up sand and grass hills of similar gradients on several aspects of running technique. The data show that running on sand is much more demanding than grass and causes a significant lowering of running velocity. This finding is consistent with the results of physiological energy demand based studies such as Lejeune et. al, (1998), Pinnington and Dawson (2001a), and Pinnington and Dawson (2001b). The results also show that ground contact time is significantly greater and stride rate is significantly reduced when running on sand. Given that the subjects were running at maximum effort, the increased ground contact time suggests a greater muscle loading effect when running on sand. Since running speed is determined by stride rate × stride length the average stride length can be estimated from the stride rate and running speed data. Further inspection of these data indicate, average stride length values of 1.77m and 2.67m for sand and grass respectively.

The ratio of contact time / stride time is significantly increased on sand indicating that sand running disrupts the normal timing of the stride pattern. The presence of a surface × trials interaction effect on stride rate suggests that subjects may not have been completely recovered between trials. These two modes of hill training are frequently used by the elite athlete subjects in this investigation as forms of 'running conditioning training' and therefore they would not normally have a full recovery between repetitions. It is probable that by habituation, some of the subjects did not allow themselves a full recovery between trials. The significant main effect for side and the surface × side interaction effect on ground contact times suggests that subjects may have 'favoured' one leg and that this 'favouring' effect on contact times is surface related. This may be due to strength differences between subjects' legs but in the absence of specific leg strength data on the subjects this cannot be verified. The results of the analysis of the thigh range of motion data indicates that subjects used a greater range of motion on grass compared with sand. This is consistent with the earlier results, which suggested that stride length was greater when running on grass.

The analysis of the vertical displacement of the lower shank markers during ground contact period showed an apparently larger downward displacement of the marker when running on sand, however, the ANOVA on these data did not indicate a statistically significant effect. Further qualitative inspection of the video sequences was carried out to examine these data further and in many cases, it was apparent that the shank marker did drop more when running on sand. The lack of a statistically significant result for these data may be due to inconsistencies in the vertical motion of the marker in the sand caused by non-uniformity in the softness of the sand surface or the limited resolution of video digitizing when considering small movements. It is recommended that the sand dune surface may require more careful raking between trials and a smaller field of view used when capturing the video data on ground contacts.

CONCLUSION: The results of this investigation show that there are significant technical differences between running uphill on a soft sand surface compared with a grass surface of similar gradient. Sand dune running causes reductions in running speed, stride rate, stride length and thigh range of motion compared with grass. Closer inspection of the ground contact and stride time data show that sand running causes significant relative timing disruptions to the normal events in the stride cycle.

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