The Optimal Downhill Slope for Acute Overspeed Running

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Purpose: This study evaluated a variety of downhill slopes in an effort to determine the optimal slope for overspeed running. Methods: Thirteen NCAA Division III college athletes who participated in soccer, track, and football ran 40-yd (36.6-m) sprints, on downhill slopes of 2.1°, 3.3°, 4.7°, 5.8°, and 6.9° in random order. All sprints were timed using the Brower Timing System Speedtrap II. Data were analyzed with SSPS 15.0. A 1-way repeated-measures analysis of variance revealed significant main effects for the test slopes (P = .000). Bonferroni-adjusted pairwise comparisons determined that there were a number of differences between the hill slopes. Results: Analysis reveals that 40-yd sprints performed on hill slopes of approximately 5.8° were optimal compared with flatland running and the other slopes assessed (P < .05). Sprinting on a 5.8° slope increased the subjects’ maximal speed by an average of 0.35 s, resulting in a 6.5% ± 4.0% decrease in 40-yd sprint time compared with flatland running. Compared with the 4.7° slope, the 5.8° slope yielded a 0.10-s faster 40-yd sprint time, resulting in a 1.9% increase in speed. Conclusions: Those who train athletes for speed should use or develop overspeed hills with slopes of approximately 5.8° to maximize acute sprinting speed. The results of this study bring into question previous recommendations to use hills of 3° downhill slope for this form of overspeed training.

Keywords: supramaximal velocity, pitch, assisted running

The ability to efficiently accelerate and reach maximum running velocity is essential for athletic success. An athlete’s running velocity is increased by improving the physical, metabolic, and neurological components associated with sprinting. Speed can be enhanced in a variety of ways including using either resisted or assisted techniques.

Training at supramaximal running speeds might have positive implications on the adaptation of the human neuromuscular system. More specifically, research has shown that assisted methods such as towing, high-speed treadmill sprinting, and downhill sprinting produce a running velocity greater than what can be achieved under unassisted conditions, potentially as a result of increasing stride length or frequency. Downhill sprinting is also an efficient and cost-effective method for increasing an athlete’s maximum velocity. Nonetheless, the optimal slope for overspeed training has not been determined.
Four training studies have evaluated aspects of downhill sprinting, using slopes of 3° or 3.25°. Of these studies, 3 examined the effect of a combination of uphill and downhill sprinting at slopes of 3° with subjects demonstrating improved running velocity compared with controls,\textsuperscript{3,7,9} possibly because of increased stride rate, which also improved with training.\textsuperscript{7,9} One investigation, however, failed to demonstrate improvement in sprint time for a group that trained at 3.25° of slope compared with subjects who performed flatland running.\textsuperscript{10}

Only 1 study, also using a hill slope of 3°, sought to examine acute variables associated with downhill sprinting.\textsuperscript{11} In that study, subjects were filmed and timed during a 40-m sprint on flatland, as well as 3° uphill and downhill slopes. Results indicate that downhill running produced approximately 5.4% faster sprint velocity than flatland running, lending support to the idea that downhill running has a positive acute effect. According to the study, this improvement was accrued as a result of greater stride length.

Anecdotal observations\textsuperscript{1,2} and some evidence suggest that downhill sprinting has positive acute\textsuperscript{11} and chronic\textsuperscript{3,8} effects on sprinting time, velocity, and stride, despite the fact that there is no information regarding the optimal slope for such training. For the purpose of this study, the optimal slope is defined as the one that results in the fastest acute sprint time. Therefore, the purpose of this study was to determine the optimal slope for downhill sprint training.

**Methods**

**Subjects**

Subjects included 13 men who were NCAA Division III college athletes participating in soccer, track, and football. Subjects’ mean age was 20.2 ± 1.8 years. They were informed of the test procedures and familiarized with the test during a pretest orientation session. All subjects provided written informed consent for the study. This study and consent form were approved by our institution’s review board, in the spirit of the Helsinki Declaration.

**Research Design**

This study used a randomized repeated-measures research design to test the hypothesis that there is an optimal downhill slope for acute running speed. Independent variables included 5 different hill slopes. Dependent variables included electronically timed 40-yd (36.6-m) sprints.

**Hill Measurement**

The test slopes were measured using a calibrated #4-21 digital slope indicator (R&B Manufacturing, Riverside, MO). According to manufacturer specifications, the digital level is accurate within 1/10 of a degree. The level was attached to a 6-ft-long board. A variety of hill slopes were assessed, with measurements recorded every 6 ft (1.8 m), resulting in 120 ft of measured slope. The slope of each hill was determined by the average of the 20 measurements. Slopes of 2.1°, 3.3°, 4.7°, 5.8°, and 6.9° were found and used to test the subjects, because these slopes represented...
a variety of increments over a range of slopes thought to be optimal according to the literature.1,3,5

Testing Protocol

During a familiarization session, subjects warmed up and performed running-specific dynamic stretches and submaximal sprints of 75% and 90%. They then performed 2 practice runs at maximum self-perceived running speeds on each of the downhill slopes to be used in the test. After approximately 72 hours recovery, subjects returned for the test session. All subjects warmed up using an identical protocol, including 5 minutes of a light jog at 50% of their self-perceived maximum, and performed the same running-specific dynamic stretching exercises including the walking lunge, walking hamstring stretch, walking quadriceps stretch, high knee jogging, and skipping. Subjects then completed 2 submaximal sprints at approximately 75% and 90% of maximal speed. They rested for 5 minutes and then ran 7 sprints, with the order determined by a random integer generator, with 5 minutes rest between sprints. The test included 2 sprints at 0°, averaged to determine baseline sprint times, and 1 sprint on each of the 5 test slopes. All sprints were performed during calm weather with wind conditions of less than 5 miles/h on grass that was cut to a standardized 2.0 in (5.1 cm).

All experimental sprint distances were exactly 40 yd (36.6 m) determined using a fiberglass measuring tape. Sprint time was determined using a Brower Timing System Speedtrap II (Brower, Salt Lake City, UT). This timing system is an infrared laser timing device that is accurate within 1/100 of a second according to the manufacturer. The timing system was triggered when a subject removed his fingers from the pressure pad at the beginning of the sprint and stopped when he triggered a laser sensor at the end of the sprint. All sprint starts were volitional, with the starting form standardized across subjects and slopes. Subjects wore spiked shoes of their choice for each of the test sprints.

Statistical Analysis

Data are expressed as mean ± SD. The a priori alpha level was set at .05. Data were analyzed with SPSS 15.0 using a repeated-measures ANOVA to test for main effects. Bonferroni-adjusted pairwise comparisons assessed statistically significant differences between the hill slopes.

Results

Statistically significant differences in the average 40-yd sprint times were found between a number of the slopes. Results indicate that the 5.8° slope yielded a 6.5% ± 4.0% faster sprint time, representing the largest difference compared with 0°. A significantly different sprint time was found between 5.8° and all other slopes, indicating that a 5.8° slope yielded the fastest sprint time. The 5.8° slope was found to be optimal for all subjects. Mean subject performance on slopes of 2.1°, 3.3°, 4.7° was also significantly faster than on the 0° slope (P < .01) but not as fast as on the 5.8° slope (P < .05). Performance on the 6.9° slope was not statistically different than on the 0° slope (P < .01). Results are described in Table 1.
This is the first study to evaluate the effect of hill slope on acute downhill-running speed. It demonstrates that hill slopes of 2.1°, 3.3°, 4.7°, and 5.8° result in acute improvements in 40-yd sprint time. The downhill slope of 5.8° yielded the fastest sprint time compared with all other slopes assessed.

Anecdotal reports have suggested that overspeed training is important for speed development.¹² Previous research demonstrated that acute speed is enhanced when subjects run downhill at a 3° slope,³ a finding that is confirmed, in part, by the current study. Similarly, training studies have supported the idea that downhill running might be useful for chronic adaptation, as well, although this finding was not supported by Suellentrop.¹⁰ In the study conducted by Suellentrop,¹⁰ however, subjects trained only twice a week with 6 downhill sprints per training session. As a result, limited training volume might have affected research results. All previous work in this area used hill slopes of approximately 3°. A 3° slope might have been used in previous research as a result of early reports¹² or research that indicated that 3° might be an effective slope,¹¹ if not optimal. Previous research that assessed subject performance changes with hill slopes of 3° demonstrated approximately 4.6% improvement in chronic sprint times,⁷ providing evidence that this form of training can be effective even at suboptimal hill slopes. Previous research demonstrated that downhill sprint-training programs on a 3° slope resulted in a 2.4% improvement in running velocity.⁹ Kunz and Kaufmann¹¹ found that downhill sprinting on 3° downhill slopes resulted in an acute change of 5.4% faster sprint time compared with flatland running. In the current study, downhill sprinting on a 3.3° slope resulted in a 3.4% faster time than running at a 0° grade. The optimal slope of 5.8° resulted in a 6.5% ± 4.0% faster time than a 0° grade. Thus, previous acute and training studies were conducted with suboptimal slopes.

The mechanisms by which faster testing times were attained during downhill running were not specifically assessed in this study. Although not specifically assessed, the acute improvements in sprint times found in this study conceivably are a function of greater speed or a faster acceleration to peak speed. In other words, these subjects attained either an increased supramaximal velocity or an increased average velocity. It is likely that acceleration is optimized with a steeper

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Table 1  Sprint Times in Seconds, Percentage Differences Compared With the 0° Slope (N = 13)

<table>
<thead>
<tr>
<th>Slope</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
<th>% difference</th>
<th>Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>5.02</td>
<td>5.66</td>
<td>5.29</td>
<td>0.21</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2.1°</td>
<td>4.98</td>
<td>5.48</td>
<td>5.18</td>
<td>0.17</td>
<td>2.1</td>
<td>–0.11</td>
</tr>
<tr>
<td>3.3°</td>
<td>4.86</td>
<td>5.40</td>
<td>5.11</td>
<td>0.19</td>
<td>3.5</td>
<td>–0.18</td>
</tr>
<tr>
<td>4.7°</td>
<td>4.79</td>
<td>5.25</td>
<td>5.04</td>
<td>0.17</td>
<td>4.8</td>
<td>–0.25</td>
</tr>
<tr>
<td>5.8°</td>
<td>4.72</td>
<td>5.36</td>
<td>4.94</td>
<td>0.20</td>
<td>6.5</td>
<td>–0.35</td>
</tr>
<tr>
<td>6.9°</td>
<td>4.83</td>
<td>5.55</td>
<td>5.20</td>
<td>0.27</td>
<td>1.7</td>
<td>–0.09</td>
</tr>
</tbody>
</table>

ª Significantly different than slopes of 2.1°, 3.3°, 4.7°, and 5.8° (P < .01).

b Significantly different than slopes of 0°, 4.7°, and 5.8° (P < .01).

c Significantly different than all other slopes (P < .05).
slope because the body is a motionless mass at the start of the sprint, and the gravitational effect of the steeper slope assists the body into motion. Slopes that are too steep might be less optimal, resulting in increased breaking forces to prevent falling, as has been previously proposed. Historically, downhill sprint training has been thought to increase stride frequency, as was demonstrated by Paradisis and Cooke. That finding was not demonstrated, however, during an acute analysis of downhill sprinting by Kunz and Kaufmann, who reported that downhill running increased stride length.

Subjects in the current study were athletes who were competitive in college athletics representing a variety of anaerobic sports. The results of this study are most likely generalizable to populations who are most similar in experience and ability to the subjects in this study. Study performance times were somewhat slower than anticipated for all trials, possibly because of the length of the grass, the nature of the starting mechanics that including using a pressure-pad sensor to activate the timing device, and the use of electronic timing. Nonetheless, the grass, wind direction (<5 miles/h), and starting mechanics were uniform across all test conditions.

Future research should evaluate whether the optimal hill slope for acute running speed is the optimal hill slope for chronic adaptations.

Practical Application

Downhill sprinting is an efficient and cost-effective method of overspeed training that increases an athlete’s maximal speed by 6.5% ± 4.0% when performed at a slope of 5.8° compared with flatland running. Downhill sprinting performed on a slope that is too shallow or steep results in a suboptimal acute training stimulus. Results of the current study confirm the acute effectiveness of overspeed hill training and can be used to guide the design of speed- and acceleration-development programs. Programs might begin with effective but suboptimal slopes and progress training intensity to more optimal and steeper slopes, up to 5.8°, as athletes become acclimated to downhill sprinting. The results of this study are also useful for those who wish to build overspeed hills or ramps with slopes that are now known to be effective. Future research will help determine the effect of athlete training status and gender on optimal hill-slope running, the mechanism of adaptations, optimal slopes for acceleration, and the effect of chronic downhill speed training.

Acknowledgments

This study was funded by a Marquette University College of Health Science Faculty Development Research Grant.

References


