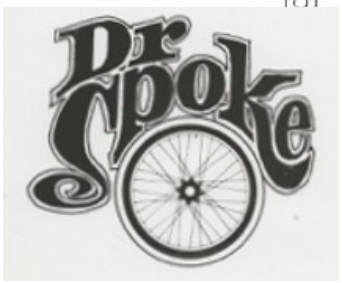
Ask Dr. Spoke



Dear Dr. Spoke: While riding I have often wondered how much wind and grade affect us. A bit tongue in cheek, but it seems the wind is always on my nose and the path continually rises. Your thoughts please.

Tuckered Rider

Dear Tuckered,

Well, you are not alone in your question and observation. I am not an expert in this but did find some interesting information on the subject. Let me offer one tidbit: Winds in the forward quarters will always feel like headwind. Hence, with a crosswind it may well feel like a headwind on both the outbound and later inbound leg.

Let's begin with wind resistance. I will draw on my aviation experience to discuss wind resistance. Wind over a wing creates an aerodynamic force (AF) whose two components are lift and induced drag. Another AF is parasitic drag ("barn door"); more on this later. Aerodynamic force increases disproportionately with higher speed. A good example of AF (lift and induced drag) is putting our hand out the wind of a fast-moving car. We all did it and observed as we rotated our wrist it increased the incident angle of wind over the palm of our hand (angle-of-attack in aviation parlance). We felt both a "lifting" action on our hand and a backward "dragging" force. Lift is actually the force created by the suction of a lower pressure on one side (the back of our hand) relative to the side into the wind. For cyclists, we aren't a wing but we do generate a lower pressure on our back as we move forward hence creating the AF components lift and drag. Both create "resistance" relative to our forward motion.

Back to the car. If one just put a hand out palm upward (like a barn door), the resulting force would be predominantly parasitic (no lifting force). The principal causes of parasitic drag are frontal area and the surface friction disrupting air flow.

Wind speed creating the AF is the summation the actual wind and the generated wind from bike speed. As a cyclist we can reduce the AF (lower pressure area on our back) through a more forward position. A rider on the drops reduces the back suction thus decreasing induced wind resistance. Recently an experienced rider told me going to the drops can reduce wind resistance by 10%. But body position does not fully eliminate drag. If the wind resistance (drag) is too high we should reduce bike speed.

We can control parasitic drag through riding apparel and reducing body area by tucking in our legs and arms. Wearing baggy riding gear opposed to form fitting jersey and shorts is somewhat equivalent to dragging a kite. Larger riders work harder in wind but not from weight; rather, it is their greater frontal area.

We are concerned about the total headwind component – bike speed and headwind. For example, riding at 15 mph with a natural headwind component of 5 mph has a total wind windspeed of 20 mph. As an aside, the headwind component is the cosine of the apparent wind (the apparent wind is the vector sum of bike velocity and actual wind velocity/direction). For example, if the apparent wind is 10 mph at 60 deg from the nose (more cross wind), the headwind component is about 5 mph. If at 30 deg, it would be about 8.7 mph (5 mph crosswind). I note crosswinds can also act upon the rider, bike frame, and wheel set creating hazardous asymmetric forces affecting stability or inducing sideways drift.

The real kicker is wind velocity. The AF increases exponentially with wind speed. For example, increasing one's speed by 10% results in approximately a 20% increase in wind resistance. In the table, note the percent change 15 mph total windspeed to 30 mph total windspeed (fourth column). A larger rider has more area creating a proportionately larger AF relative to smaller rider.

The table illustrates the wind resistance expressed in power (watts). The values come from www.exploratorium.edu (aerodynamics). The basis is a total 150 pound rider and bike (weight of itself has no effect) traveling at 15 mph. The values do not consider rider position affecting induced resistance, clothing affecting parasitic resistance, and rider area size (affects both parasitic and induced).

Headwind / Total Windspeed (headwind + 15 mph bike speed) mph	Resistance measured as effort in watts (W)	Percent change from preceding wind velocity	Percent change from 15 mph, no headwind
0/15	39 W	---	--
5/20	70 W	179%	179%
10/25	110 W	157%	280%
15/30	158 W	147%	400%
20/35	217 W	137%	556%

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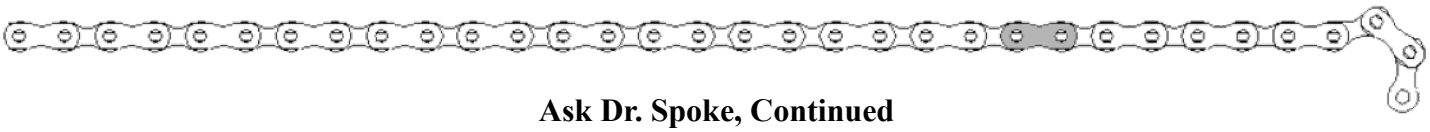

Ask Dr. Spoke, Continued

Some safety factors to consider are crosswinds and wind gusts affecting the bike and rider. Managing body position and clothing can negate wind to a point. Another factor is the bike aerodynamics. For example, the wheel set creates both lift and drag. A lower wind profile wheel (spokes and rim) will help in a crosswind. Rather than launch into a long discussion one may find some good articles by Googling "cyclist and wind." But here are some good points:

- In a headwind reduce area by keeping arms and legs inward.
- Avoid wearing loose, baggy clothing.
- Reduce drag by using the drops and forward riding position.
- Pace lines reduce effort. For quartering winds, an echelon following the wind shadow helps.
- Excessive crosswinds (for example, 35 mph) and high gusts are hazardous as wind (drag) can couple with bike and rider to create uncontrollable drift or balance. Use extreme caution in pace lines/pelotons.
- Anticipate wind gusts as large vehicles pass especially in crosswind conditions.
- Reduce bike speed by one half of headwind. For example, in 10 mph headwind the rider would reduce speed from 20 mph to 15 mph.
- Maintain cadence and shift to lower gear (constant effort)—don't hold constant speed.

The second question: the comparison between wind speed and grade. Simply, it is a bit more complex. Weight not a factor for wind but is a large one for climbing. So using the same algorithm as for winds, I created the following table. I used zero headwind, two rider weights (130 lbs and 180 lbs) and bike weighing 20 lbs. The two values for speed are for constant 15 mph and for varied speed to maintain more or less constant power (watts) for 150 lbs. Grade is the sine of path angle in percent (vertical rise in 100 feet). Note, the values in the 200 lbs total weight provide comparative effort. Not surprisingly, power output on level ground is independent of weight.

Speed Constant / Varied	Grade (angle / percent)	150 lbs total weight (constant / varied) W	200 lbs total weight (constant / varied) W
15/15	0º / 0%	39/39	39/39
15/14	1º / 2%	117/105	143/129
15/10	2º / 3.5%	196/115	248/150
15/7	3º / 5%	274/113	352/149
15/6	4º / 7%	352/127	456/169

The general observations regarding grade and speed are clear. Of course, what is truly evident is the effect of weight and climbing. The amount of power varies directly with weight: a one percent increase in weight results in a one percent increase in power required. The same point in wind applies, as grade increases (effort), the rider should reduce gears, maintain cadence, and lower speed. For touring bikes a good rule is not to try and accelerate approaching a climb. Rather, downshift and roll into your climbing speed.

There is a minimum safe speed for any rider. For me, much below 3 mph and I need to dismount. One amusing anecdote occurred a few years ago on a tour and a relative steep ascent. As I labored to pedal at a very slow speed, the rider about 60 feet in front of me dismounted. It took me about 10 minutes to pass amidst his derisive laughter.

One may ask, what is the normal power output for a cyclist? It is a bit complicated and beyond the scope of this article. But for reference a pro cyclist sustains between 200 and 300 watts of power on a four-hour stage. For a better discussion check out this article https://www.roadbikerider.com/average-wattage-cycling/ .

An answer to the question: A 150 lb bike and cyclist climbing a 1% grade at 15 mph is roughly equivalent to pedaling into a 25 mph combined wind (speed and headwind component).

Hopefully I didn't bake your noodle too much.