Understanding Running Effectiveness and its Uses

by Steve Palladino

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Introduction

Running Effectiveness (RE) is a metric developed by Andrew Coggan, PhD. In his July 2016 article, WKO4: New Metrics for Running With Power, Dr. Coggan wrote:

> Running effectiveness is a novel metric presently unique to WKO4. It is calculated as the ratio of speed (in m/s) to power (in W/kg, or (Nm/s)/kg), resulting in the units of kg/N. It can be viewed as the inverse of the effective horizontal retarding force that a runner must overcome to achieve a particular speed. For most experienced runners, running effectiveness is typically close to 1 kg/N. Running effectiveness may be lower in novice or fatigued runners since they do not travel as fast for a given power output or must generate more power to achieve the same speed. Running effectiveness may also decline slightly at higher running speeds, when running above critical pace for example.
>
> Note that running effectiveness is not the same as running economy or running efficiency. The former is the ratio of metabolic cost, i.e., VO2 or sometimes metabolic power, which accounts for small differences in energy yield per unit of O2 consumed, to running speed. The latter is the ratio of external mechanical power output to metabolic power production.

With this metric, Dr Coggan created one of the most important metrics associated with running with power.

RE is a simple yet very powerful metric. The equation is quite simple:

RE = speed/power
(where speed is in meters per second and power is in watts per kilogram)

Therefore: RE = (m/s) / (W/kg)

Just as the metric Functional Threshold Power (FTP) allows an athlete with field data from a power meter to estimate a marker of metabolic fitness similar to lab-derived Maximal Lactate Steady State (MLSS) or Lactate threshold (LT), so too Running Effectiveness allows an athlete with field data from a power meter to estimate a marker of effectiveness that is a surrogate for lab-derived Running Economy. In the case of Running Effectiveness (RE), the greater the value of RE, the more effective the runner is at converting external power into speed.

Common applications of RE

As a summary metric

RE can be evaluated as a summary metric of a run, race, interval, or run segment. As such, we can assess how effective a runner is at converting external power into speed over a defined run, race, interval, or run segment. In doing so, we must acknowledge that RE is sensitive to intensity (power-duration) (see figure 1).

Figure 1. Mean maximal RE curve

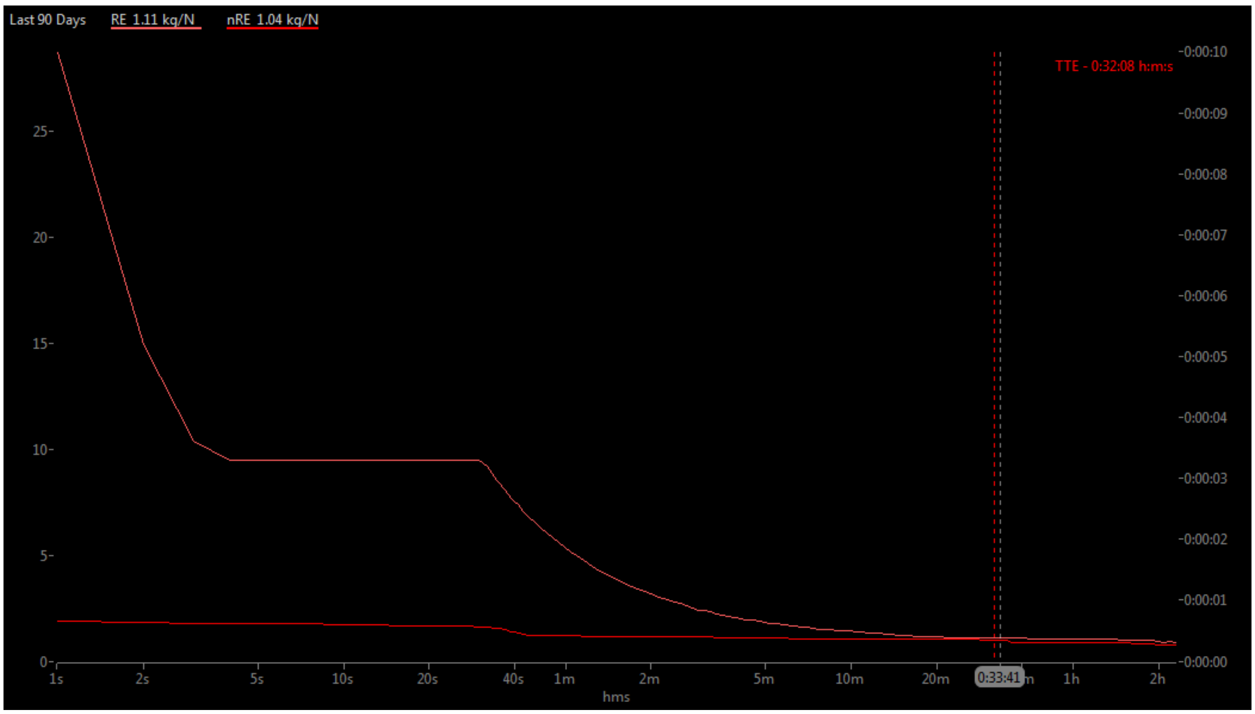
Y axis = RE

X axis = duration scaled logarithmically

RE = Running Effectiveness (pale line)

nRE = normalized RE (red line)

TTE = time to exhaustion at FTP (vertical dotted red line)



We can see that RE (the paler line) slopes considerably over shorter durations, flattening out/stabilizing near 20 minutes of duration. At shorter durations (higher intensities), RE is typically higher than seen at durations of 20 minutes or more. When RE is normalized to intensity (the red line), the reported values are more stable to intensity (flatter line across all durations). Therefore, it is best to interpret RE at a set intensity, such as RE at FTP, or RE in 5k races, RE in 10k races, etc.

RE is also sensitive to grade. RE is lower when running uphill, given that speed is suppressed while power is not. Conversely, RE is higher when running downhill.

RE may also be similarly sensitive to wind, since in a head wind, speed is suppressed while power is relatively less affected, resulting in a lower RE.

Therefore, at FTP, on relatively flat terrain, in good running conditions, it is likely that:

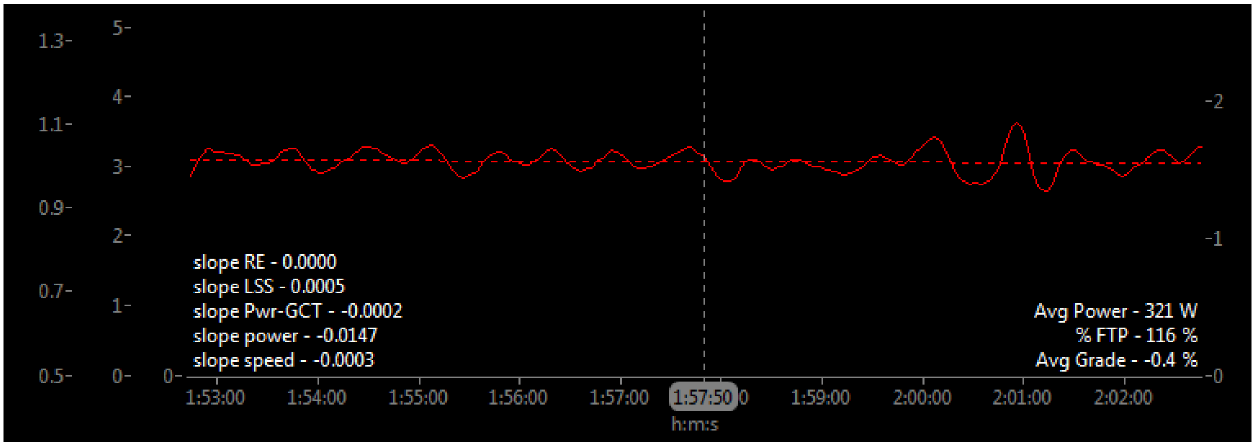
RE = 0.99 to 1.01 is near average
RE = <0.99 is below average
RE = >1.01 is good
RE = >1.05 is likely the realm of elite world class runners

Again, the greater the value of RE, the more effective a runner is at converting external power into speed.

To analyze the impact of grade and wind

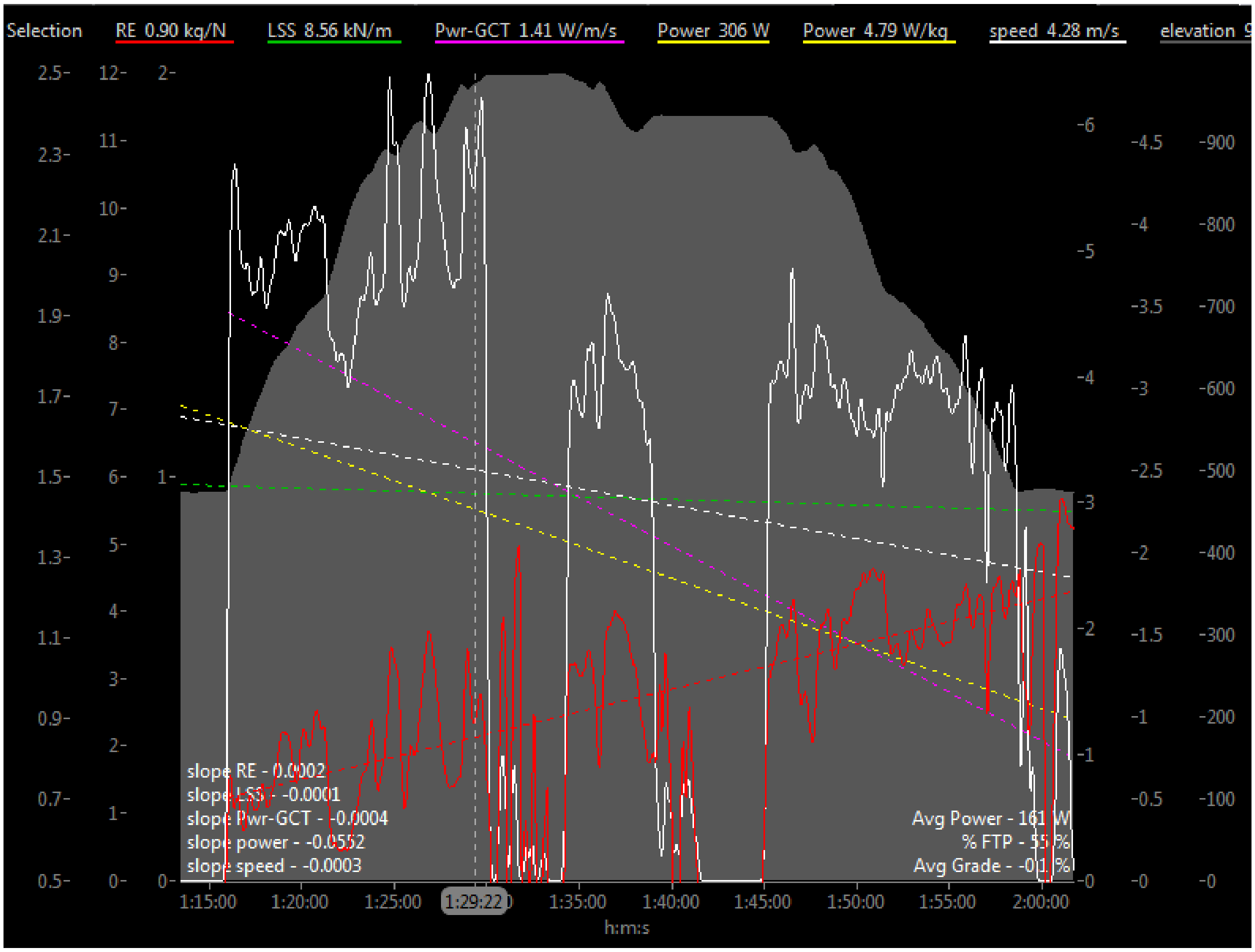
RE can also be tracked continuously in a chart of a run, race, interval, or run segment. In doing so, we may see the impact of grade or wind. Additionally, RE can be a gross indicator of fatigue, particularly on flat terrain without large changes in environmental conditions (figures 2-4).

<u>Figure 2. 3200m track race in heavy wind conditions.</u>
X axis = Time
Y axis = RE
RE = solid red line (SLR line dotted red)



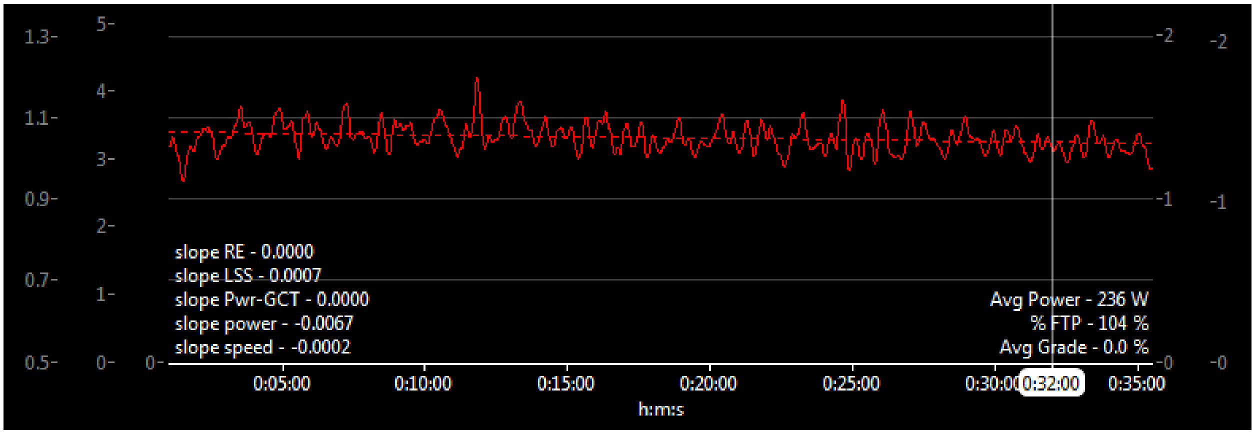
This race was on a track in heavy wind conditions. Particularly in the first half of the race, one can see that RE forms a recurring, sinusoidal wave appearance. In this case, RE falls as the runner runs into a head wind on one straight and rises as he runs with a tail wind on the opposite straight.

<u>Figure 3. Uphill tempo and easy downhill return.</u>
RE = solid red line (SLR line dotted red)
Speed = solid white line (SLR line dotted white)
Elevation profile in grey background.



We can see that despite higher speed (and power, though not shown) on the uphill segment, RE is lower than on the easy downhill return. Typically, RE is suppressed on uphills and amplified on downhills.

Figure 4. 10,000m track race.
RE = solid red line (SLR line dotted red)



Note the subtle lower trend in RE depicted by the SLR line, suggesting a fatigue effect. If we compare the last 2500m to the first 2500m, we notice a 3.6% decline in RE.

Caveats

- RE is sensitive to intensity. It is best to compare RE at a set (or tight range of) intensity.
- RE is sensitive to grade. It is best to compare RE as a set (or tight range of) grade.
- RE is sensitive to wind. It is best to interpret RE in light of the possible net effects of heavy wind.
- RE is dependent upon accurate power and weight data to calculate the W/kg component, and accurate distance and duration data to calculate the speed (m/s) component. In other words, garbage in, garbage out (GIGO).

Nevertheless, understanding RE is critical to understanding the relationship of power to speed in running.

In running, actualized speed is not solely the product of gross external power generated. Two runners may have exactly the same power-weight ratio over a 10,000m course, yet of the two, the one that is most effective at converting external power into speed (in other words, the runner with the higher RE) will be the one capable of producing the faster time. To help clarify the relationship, let’s rearrange the RE equation:

RE = speed/power
RE = (m/s)/(W/kg)

Rearranged: Speed = RE * Power
(m/s) = RE * (W/kg)

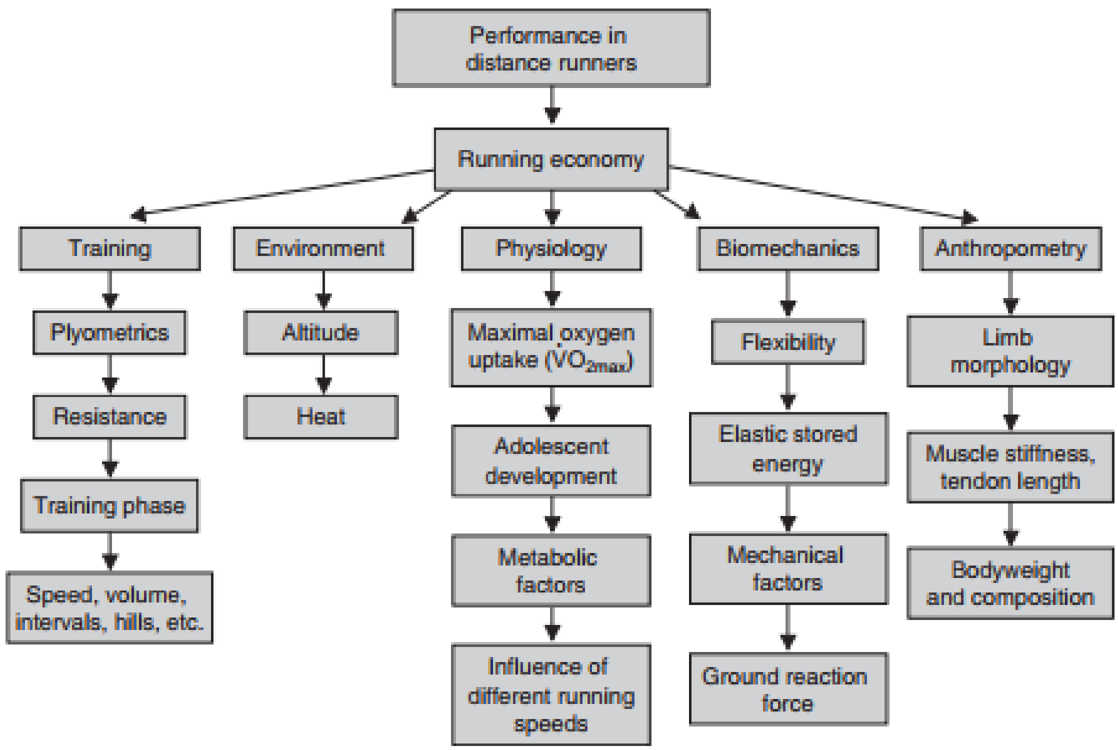
We can begin to appreciate that to improve running speed, we must improve: a) power (W/kg), b) RE, or c) both. Improving speed (or pace, or performance time over a fixed race distance) in running is not simply about improving power. Improving efficiency, or the effectiveness at which a runner can convert external power into speed, can also have a positive effect on improving speed (or pace, or performance time over a fixed race distance).

Knowing this equation and relationship allows coaches and runners to design training programs to develop not only power (W/kg), but RE as well. It has been my experience that gains in power are easier to achieve with training manipulation than are gains in RE, but nevertheless, attempting to improve RE (to improve the effectiveness at which a runner can convert external power into speed) is a worthwhile complimentary training focus.

How to improve RE

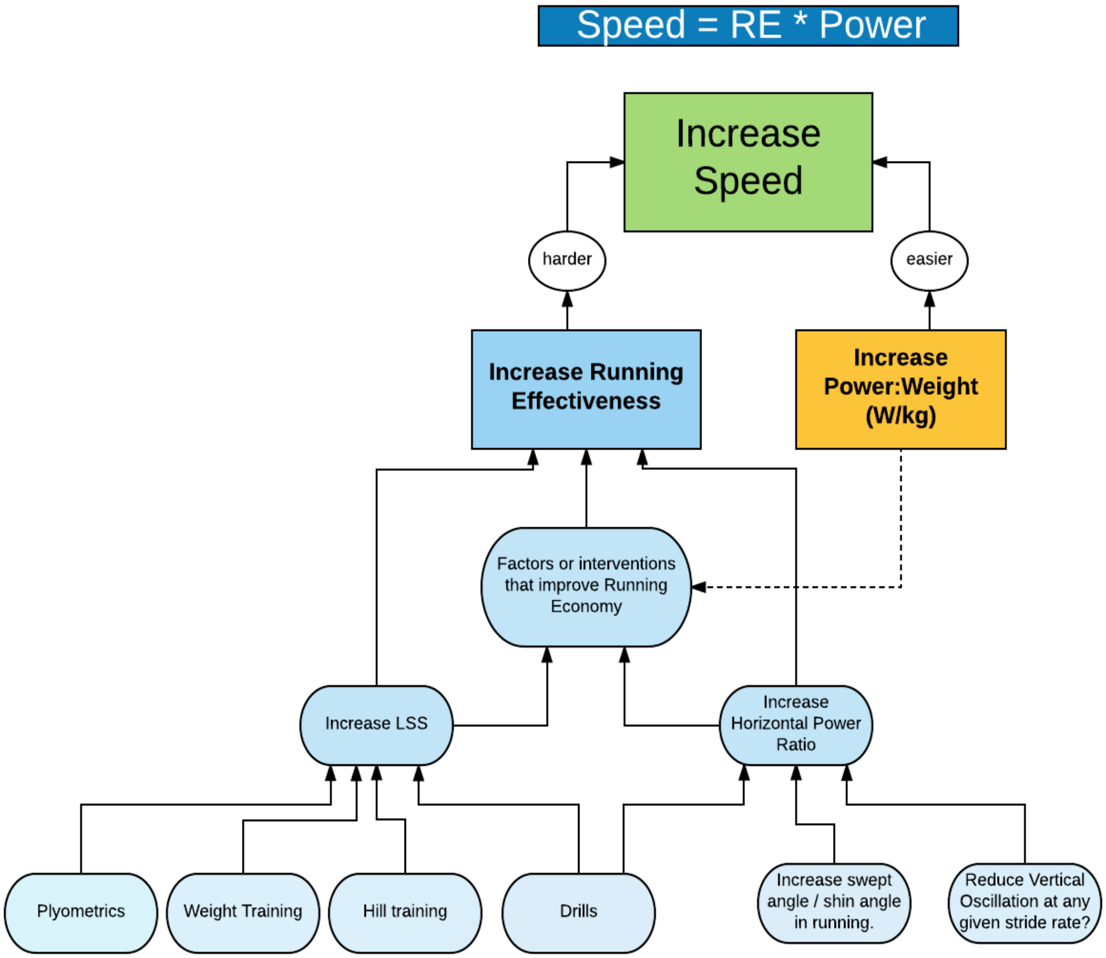
Improving RE is not an easy task (at least not as easy as improving power). That said, the converse is true: frittering RE away is not likely to be seen in actively training runners. In the end, the gains (or losses) will likely be subtle.

To improve RE, it might be helpful to look into research on Running Economy (Saunders et al-2004, Barnes and Kilding-2015, Stryd Team-2016). (Note: Running Effectiveness is not the same as Running Economy. In this article I abbreviate only Running Effectiveness as RE and will not abbreviate Running Economy.) The determinants of Running Economy are numerous and multifactorial, as depicted by Saunders et al (Table 2, p470) in this image:



It is likely that simply developing an athlete's power-duration curve over time will advance Running Economy to some extent. Therefore, it is also likely that developing an athlete's power-duration curve over time may have some positive effect on Running Effectiveness (RE), as well. This relationship is alluded to in the dotted line in Figure 5.

Figure 5. Depiction of contributors to RE using the rearranged RE equation.



In addition to factors or interventions that may improve Running Economy (Saunders et al-2004, Barnes and Kilding-2015, Stryd Team-2016), there are two actionable metrics generated from Stryd running power meter data that likely factor into Running Effectiveness (RE): leg spring stiffness (LSS) and horizontal power ratio (HPR).

RE may improve when improving leg spring stiffness (LSS).

LSS may be related to physical properties of tendons (such as the Achilles tendon), ligaments and fascia structures (such as the plantar fascia), and myofascial elements. It has been proposed that on loading, during contact through the midstance phase of running, these structures store elastic energy. Following midstance, through propulsion these structures provide some elastic recoil. Hence, these structures may account for some or all of the spring effect captured by the metric LSS.

Because LSS is essentially a measure of elastic recoil, it represents speed with no metabolic cost; no oxygen is utilized in the elastic recoil process. Building LSS is "free speed," which translates into improved Running

Economy (greater speed without greater oxygen utilization) and is likely reflected in improved Running Effectiveness (RE).

For comparison purposes, it is best to normalize LSS by weight (LSS/kg). Based on data I have evaluated, LSS/kg stratification may fit as follows:

95th percentile:	0.173
Above average:	0.158
Average:	0.143
Below average:	0.128
5th percentile:	0.113

LSS may respond to interventions such as plyometrics, weight training, hill training, and drills. A sample program is available here.

RE may improve by improving horizontal power ratio (HPR).

Horizontal power is the component of gross external power (the power reported by a Stryd running power meter) that is directed horizontally. If we look at the relative percentage of horizontal power relative to gross external power (Stryd power), we are analyzing the horizontal power ratio (HPR).

The higher the HPR, the more effective an athlete is at directing gross external power (Stryd power) horizontally. For example, if two athletes each run 5000m at an average of 300 watts and one had an HPR of 77% and the other 80%, all other things being equal, the runner with the HPR of 80% goes faster, since more of that athlete's 300 watts are directed horizontally.

HPR is variable between athletes. Also, within a given athlete, HPR typically increases with speed. It's best to compare athletes' HPR (and for that matter, a given athlete's HPR over time) at a fixed intensity. For example, HPR at FTP, or HPR in 5k races, or HPR in 10k races, etc.

Therefore, at FTP, on relatively flat terrain, in good running conditions, it is likely that (approximately):

HPR = 76-78% is near average
HPR = <76% is below average
HPR = >78% is good
HPR = >80% is likely the realm of elite world class runners

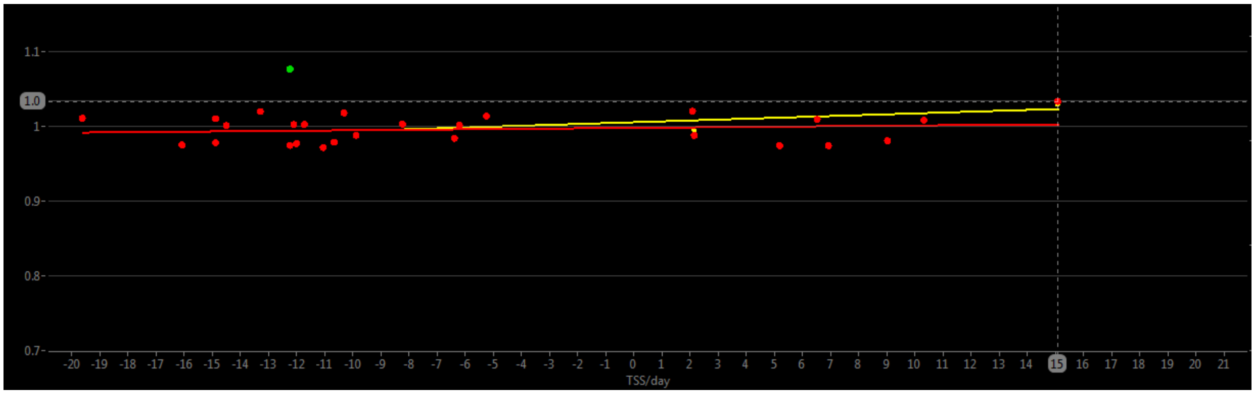
Again, the greater the value of HPR, the more effective a runner is at directing external power horizontally.

HPR may respond to interventions such as:

- Drills. The wall drill (or fence drill) would be an example.
- Increasing SI and hip extension (resulting in increased swept angle and shin angle). Examples might include anterior hip flexibility work and extension strengthening like hip thrusts.
- Dynamic stride work. Using dynamic data, we could work on reducing vertical oscillation while maintaining cadence and speed/power.

Besides the training interventions noted in Figure 5, we must also consider another potential factor of improving RE: relative freshness. [Training Stress Balance (TSB)]() is a training load metric that reflects relative residual fatigue, where a more negative value reflects more residual fatigue and a more positive value reflects progressively less residual fatigue and more freshness. I have noted that RE can be seen to slightly increase with a less negative/more positive TSB (Figure 6).

Figure 6. RE versus TSB.
X axis = TSB
Y axis = RE
RE vs. TSB = red simple linear regression line
RE vs. TSB for races only = yellow simple linear regression line



In both cases we can see a modest positive correlation of RE with increasing TSB.

Hypothetically, it could be that RE may also correlate with sleep or HRV in a subtle fashion, as well.

In the end, improvements in RE are harder to come by than improvements in power. Nevertheless, RE improvement offers an additional pathway to improving speed. The extent to which a coach or runner pursues those gains may be guided by (among other things) the runner's baseline RE and available training time—in other words, an assessment of return on investment.

Other uses for RE

Predicting time from anticipated power and RE

If power (in W/kg) and RE can be reasonably estimated, then speed can be predicted. Speed = RE * (W/kg)

In turn, if speed can be predicted and race distance is known, then a finish time can be predicted based on expected power and RE. Time = distance / speed

For example, we might be able to reasonably accurately predict a target power for a given distance/duration based on functional threshold power (FTP), performance in key workouts, the WKO4 power-duration model, and/or the modified Riegel formula (Riegel 1981, George 2017, George 2017).

Similarly, RE can be estimated based on RE in prior races, key workouts, WKO4 modeling in which RE is normalized to intensity and FTP time to exhaustion, and perhaps even the modified Riegel formula. It helps that on flat terrain, RE is reasonable consistent for durations of 20 minutes to perhaps 2 hours, with perhaps no more than 0.02 spread over those durations.

Let's use a project half marathon time as an example. Let's say that a power target of 280-285 watts is possible for a given runner, that we know the runner will likely run the race with an estimated RE of 1.00 to 1.01, and that the runner weighs 67 kg. A RE of 1.00 and an average power of 280 watts (4.12 w/kg) produces a speed of 4.12 m/s, or a half marathon time of 1:25:21. A RE of 1.01 and an average power of 285 watts (4.25 W/kg) produces a speed of 4.12 m/s, or a half marathon time of 1:21:51. Of course, the tighter the estimates for power and RE, the tighter the predicted finish time (and pace, for that matter, if we use such an increasingly outmoded metric).

Predicting power requirement for hitting a desired time for race distance

hen starting a training program for a given race, a runner might be interested in looking into the power that will be needed to meet a goal time for the race. To do so, we must have a reasonable estimate of the athlete's RE for the given course and distance. We must then arrange the RE formula to:

Power (in w/kg) = speed (in m/s) / RE

Let's say an athlete sets a goal of breaking 3:00 for a marathon. A 3:00 marathon is run at a speed of approximately 3.91 meters per second. We must then estimate the runner's RE for a marathon and for the course, based on RE in prior races, key workouts, WKO4 modeling in which RE is normalized to intensity and FTP time to exhaustion, and perhaps even the modified Riegel formula. For example, if a runner can be predicted to run a marathon with an RE of 0.99, then a 3:00 marathon will take 3.95 W/kg.

Power = (3.91 m/s)/(0.99) = 3.95 W/kg

Of course, the 3.95 W/kg can be used to calculate actual target power by multiplying by the runner's weight in kilograms. Assuming a weight of 70 kg in this example, the target power would be 276.5 watts. Planning further, if the runner has a kilogram to shed can train down to a race weight of 69 kg, the necessary power for the 3:00 marathon would become 272.6 watts.

We could go a step further and, by using the modified Riegel formula, calculate the requisite FTP/CP from the requisite marathon target power.

Stratifying potential

RE can be used, in part, to stratify potential across athletes. In order to make proper comparisons, RE should be standardized to RE at FTP and on flat terrain. With those caveats, runners can be reasonably compared. A relatively higher RE may represent a higher potential for fast race times, if power is properly developed.

Comparing shoes

By carefully comparing repeated alternating bouts of running in different shoes, a runner might gain insight into which shoe produces a higher RE. These bouts should be on a treadmill, where speed is controlled. If varying speed is used, or if the testing is done over ground, regression analysis of the data for each shoe is necessary. Even under ideal circumstances, it is possible that small differences may be masked by measurement and protocol errors.

Summary

Running Effectiveness (RE) is one of the most important metrics to be developed for the analysis of data from a running power meter. The metric holds the key to understanding the relative relationship between running speed and running power.

The impact of this metric is made even greater by the fact that it produces this information—the effectiveness with which the runner converts external power into speed—from data collected in the field. Although not easily responsive to intervention, Running Effectiveness is, nevertheless, an actionable metric.

Lastly, besides offering an actionable metric that reflects an athlete's effectiveness at converting external power into speed, the metric has expanded potential within prediction models and other alternative uses. Because of its importance, the metric should be followed by coaches and athletes as closely as power itself. That it is not, at this time, routinely calculated on most analysis platforms (WKO4 being an exception) should not deter coaches and athletes from following this metric through alternative workflows, or from requesting that the metric be provided to them on the platform of their choice.