2. How good and reliable are power meters in running?

Your performance in running is primarily determined by 2 factors. These are your maximum oxygen uptake capacity VO_2 max and your running economy RE. A higher VO_2 max enables your muscles to produce more energy, so your 'human engine' has more power. However, your race time is not only determined by the power of your muscles, but also by your running economy (RE). Your RE determines how much energy you need to run 1 mile, comparable to the gas mileage of your car. A lower RE means that you run more economically, so you can run faster at the same VO_2 max. Your RE is related to your running form, as vertical and lateral movements increase the energy cost of running. Runners and coaches usually spend a lot of time trying to improve running form, but so far they could not measure the impact on the RE. With the breakthrough of running power meters, you can now measure your RE on a daily basis. This means you can see the impact of changes in your running form on the energy cost of your running. This provides the exciting opportunity to optimize your running form, energy cost and race times!

In the past decade, power meters have revolutionized training and racing in cycling. Right now, we are at the eve of a similar breakthrough of power meters in running. We have tested the Stryd Pioneer power meter and were impressed by the results. We believe the concept holds great promise to improve training and racing in running, just like it has done in cycling. In this paper, we will discuss the measuring principle of the Stryd, our tests and the advantages in running, as we see them. For more information on the theory and practices of running with power we refer to our book ***The Secret of Running*** (www.thesecretofrunning.com).

Measuring principle of the Stryd

The Stryd is based on the use of accelerometers. These are small chips, that can measure accelerations. Nowadays, accelerometers are very cheap and accurate and they are present in many devices, such as smartphones, tablets and running watches.

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The Stryd Pioneer is attached to a chest band that also measures your heart rate (photo). You can easily connect it to your running watch or smart phone. Sensors measure the acceleration of

your body in 3 directions: horizontal, vertical and lateral. Obviously, in running you want to limit the vertical and lateral movements as they increase the energy cost and do not contribute to the forward movement! An App allows you to input your body weight m (in kg). The Stryd uses this to calculate the running power P (in Watt) from the measured accelerations a (in m/s^2, in 3 directions) and the velocity v (in m/s) with the formulae:

F = m*a
P = F*v

The breakthrough of the Stryd is their software that calculates in real time the power from all sensor data. As a runner, you now have the added information of your wattage available on your running watch or smart phone. After your workout or race, you can analyze all the data on your PC, so you get a complete picture of the amount of power that your human engine has produced. This allows you to optimize your training and particularly your running form so you can more economically, reducing the energy cost of running.

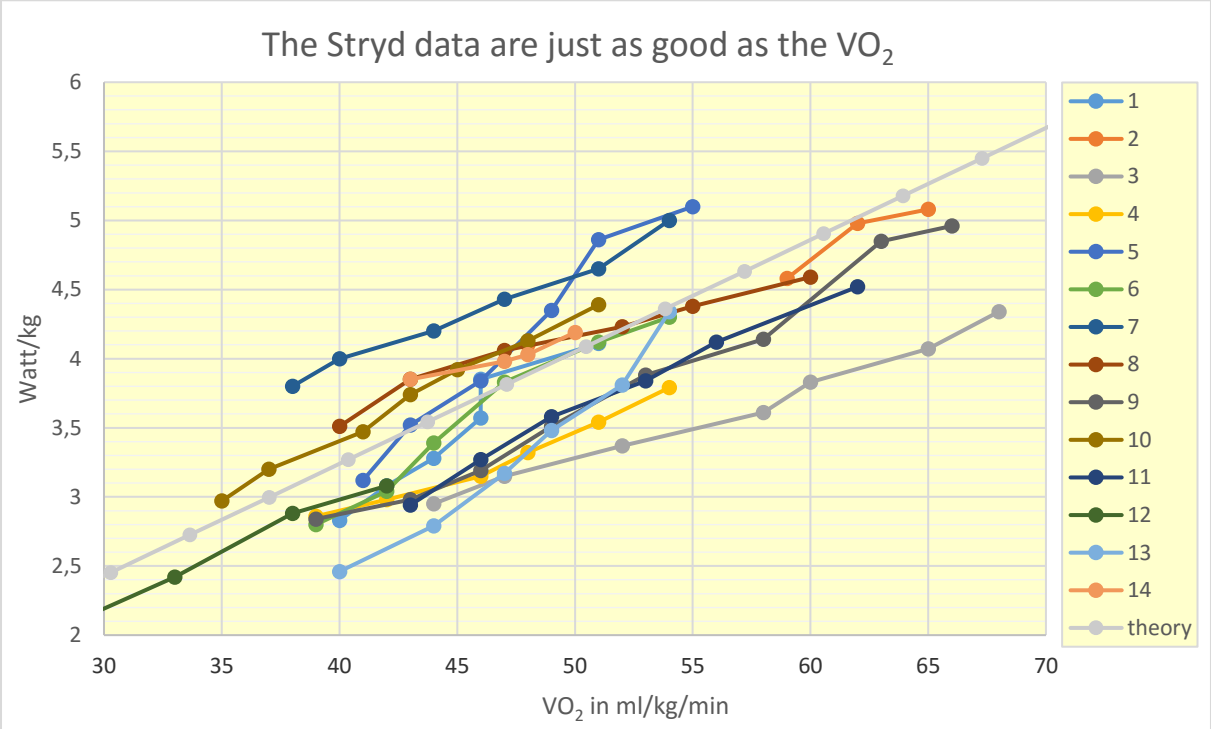
How good and reliable is the Stryd?

We have tested the Stryd at the Dutch Sports Medical Center SMA Midden Nederland. In the test 14 runners (including authors Hans and Ron) were tested in a standard exercise stress test on a treadmill. The test started at a relatively low speed (10 km/h), which was stepwise increased every 3 minutes. The oxygen uptake VO_2 was measured continuously with a breathing cap. Simultaneously, the power was measured with the Stryd, so we could compare the power data with the VO_2. The picture shows author Hans and the measuring equipment with Guido Vroemen behind the monitors.

The test results

The results were quite convincing. We found that an increase in the treadmill speed resulted in a proportional increase of both the VO_2 (in ml O_2/kg/min) and the specific power SP (in Watt/kg). The graph shows the data for all 14 test persons and also a line representing the theoretical relationship, which we derived in our book:

SP = 0.08125*VO_2



The graph clearly shows that in general the data match well with theory. The differences between individual runners will be caused by the fact that there running form and energy cost of running are not the same. As an example runner 7 (the dark blue line) uses a lot of power, so his energy cost is high. This may well be caused by excessive vertical or lateral movements.

Conclusions based on the test

We were most impressed by the results. Beforehand, we had not expected the Stryd data to be just as good as the VO_2, which is worldwide regarded as the golden standard of physiological tests! We have concluded the following:

1. The Stryd data are quite realistic and reliable.
2. The Stryd data match the VO_2 -measurements and are in accordance with theory.
3. When used on a daily basis, the Stryd data provide a wealth of information on the power of your human engine. Previously, these data could only be obtained occasionally by measuring the VO_2 max in a physiological laboratory.

Running economy, running efficiency and energy cost of running

One of the most exciting features of the Stryd is that it provides us with the possibility to measure how much energy we need to run 1 mile or 1 km. Obviously, you should try to prevent wasting of energy. So it is very important to use as little energy as possible. Some authors use the term Running Economy (RE) to describe this, others use the term running efficiency. This does not matter as both terms relate to the energy cost or running (ECR). So, what is this energy cost

of running, how much energy do we use to run 1 km? In the standard textbooks, this is usually set at 1 kcal/kg/km. Obviously, this is just an average number. In real life, the Kenyan and Ethiopian elite runners will use less energy, whereas pounding and puffing joggers will use more. The power meter now gives us the opportunity to measure the energy cost of our running in real-time. Next we can try to minimize the energy cost of running through improvements in our running form. Finally, when we minimize the energy cost of running, we can improve our race times, even at the same power of our human engine!

The impact of running form

What is the secret of a good running form? Coaches and runners usually have strong, but different opinions on this. In literature, the following factors are often thought to influence running form: cadence, ground contact time (GCT), stride length, oscillation, arm drive, foot strike, hip angle, knee lift, leg stretching, calves lift, ankle angle and breathing rate. But what is the impact of all these parameters on the energy cost of running, how can you reduce your energy cost to the minimum?

How can we measure the energy cost of running?

Traditionally, the energy cost of running is measured in the physiological laboratory and expressed as the amount of oxygen used to run 1 km (per kg of body weight, the unit is ml O_2/kg/km). This is denoted as the Running Economy (RE). Kenyan elite runners like Wilson Kipsang have an RE of only 180 ml/kg/min, average runners use around 210 ml/kg/km, but some of the runners in our test needed no less than 240 ml/kg/km. This means that these runners use much more oxygen to run at the same speed as Kipsang! Consequently, a high RE means that you are NOT running economically (and NOT efficiently) and the energy cost of your running is high. Obviously, this also means that you will run slower than another runner with the same VO_2 max.

In our book The Secret of Running (www.thesecretofrunning.com), we have derived the table below to illustrate the big impact of the RE. Please have a look at the row of an hour speed of 15 km/h. The table shows that a runner with an RE of 180 ml/kg/min needs only a VO_2 max of 51 ml/kg/min to maintain this speed during 1 hour. However, a runner with an RE of 240 ml/kg/km needs a VO_2 max of no less than 68 ml/kg/min to maintain the same speed of 15 km/h! In our book, we have shown that the ultimate limit of world class athletes is a VO_2 max of around 88 ml/kg/min, so the higher (white) values in the table are not realistic in practice.

Required VO_2 max (ml/kg/min)			
	RE	RE	RE
v_{hour} km/h	180 ml/kg/km	210 ml/kg/km	240 ml/kg/km
10	34	40	45
11	38	44	50
12	41	48	55
13	44	52	59
14	48	56	64
15	51	60	68
16	55	64	73
17	58	68	77
18	61	72	82
19	65	76	86
20	68	80	91
21	72	84	95
22	75	88	100
23	78	91	105
24	82	95	109
25	85	99	114

How can you optimize your running form, using the Stryd?

Using the Stryd, you can now measure how much power you use to run at a specific speed. This allows you to calculate your RE with the formula derived in our book:

RE = 205*SP/v

As an example we use a runner with a body weight m of 70 kg, who runs 15 km/h (4.17 m/s) and uses 287 Watt. Consequently, his RE is 287/70/4.17 = 201 ml O_2/kg/km.

Once you have determined your RE, you can try to optimize your running form, by changing your cadence, stride length, arm drive, running style, etcetera. The power data of your Stryd will then tell you whether the changes lead to a reduced energy cost of running. This means you can now finally see for yourself which running form is the best for you! Of course, changing your running form is not an easy matter, but now you can work systematically towards the best possible result. If all goes well, your hard work should result in faster race times.

The (potential) benefits of power meters in running

We believe the Stryd has great potential for optimizing our running. The additional power data offers many potential advantages, including:

1. For the first time, you can determine your RE on a daily basis and see which factors impact the energy cost of your running.
2. For the first time, you can train systematically to improve your running form and reduce the energy cost of your running. This holds the promise of improving your race times, even at the same VO_2 max.

3. You get a better picture of your workouts, so you can optimize them. Power is the best and most accurate reflection of the intensity of your workout.
4. You get a better picture of your fitness, so you can peak at the right time. This means you can avoid overtraining and taper correctly.
5. You can maintain perfect pacing throughout the race, independent of (changing) conditions such as hills, wind, etcetera.
6. You can share all information with your coach, so you get better guidance.

Of course, these advantages still need to be proven in the daily practice of runners worldwide. We have used the Stryd Pioneer for several months and have already derived useful conclusions on all of the above aspects. An example is that we have seen that we can reduce the energy cost of our running by as much as 10%. In future papers, we will discuss this in detail. We are curious to the reactions and experiences of the readers, we welcome you to share these at www.thesecretofrunning.com

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www.thesecretofrunning.com