Polar Running Power

Jul 17, 2018

Polar Research and Technology

Contents

1 Introduction

Running Power is a Smart Coaching tool that allows runners to keep track of their external load as well as use it as an interval and slope training guide. Running Power complements but does not replace heart rate tracking.

Running Power combines information from speed, changes in speed, and current altitude gradient. The end result is a single number which represents the power that our muscles supply during running.

Running Power is not to be confused with daily energy expenditure, which is the amount of energy that cells extract from food every day. To highlight this, Running Power uses the unit of watts whereas energy expenditure is given as kilocalories per day. Although conversion from watts to calorie consumption rate is possible, it is not recommended as these numbers measure two completely different phenomena.

The demand for running power has persisted since the appearance of power in cycling. However, it is crucial to understand the difference between running and cycling power.

Bicycles use sensors installed on the pedals to yield torque and angular velocity. Cycling power is then calculated as their product. In runners, there is no universally accepted location or place where a sensor could be worn to measure running power.

Consequently, running power sensors are worn on various locations on the body; such as foot, waist or chest, depending on manufacturers preference. This is about to change. Polar is the first to offer running power for runners on a wrist-worn device.

The purpose of this paper is to decribe Polar Running Power, what inputs it uses and what the benefits are for the user.

2 Definition of power

In physical sciences, power is the rate of change of energy. Thus power does not exist without energy.

When a runner is moving, there must be energy related to motion. This is called kinetic energy. As the runner also fluctuates up and down in earth’s gravitational field, there must be energy related to position. This is called gravitational potential energy.

Together kinetic and potential energy are called mechanical energy. Thus it’s possible to define running power as rate of change of mechanical energy of a runner.

2.1 Unit of power

The following three units of power are supported:

Watt (W) as standard SI unit.

Watts per kilogram of body mass (W kg^{-1}). This allows comparison of individuals of different size.

Percentage of maximal aerobic power (MAP). Runners can get an individual estimate of their MAP with either time- or distance-trial test.

3 Polar Running Power

Running Power has been defined as rate of change of mechanical energy. But how can running power be determined experimentally? This section covers that topic.

The first attempts to determine running power were conducted using technique called motion analysis, where motion of each body segment (e.g. lower leg and thigh) is measured with high-speed cameras. Then a model of human mass distribution, deduced from cadaver data, is used to calculate fluctuations in motion of body's center of mass (COM). This is a time consuming process.

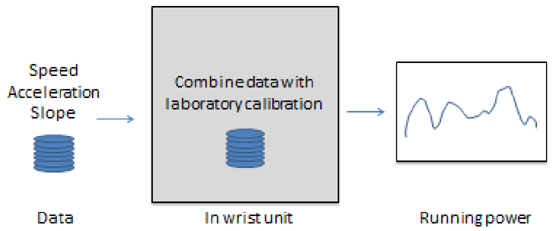

Figure 1. Principle of Polar Running Power.

To streamline the determination of running power, Giovanni Cavagna used forceplates as ergometers.[1] As force plates measure directly the fluctuations of the COM, his method did not require working out the motion of each mass segment and converting that to the motion of the COM.

The work of Cavagna is the backbone for Polar Running Power. As shown by Cavagna, on flat surface running power is a linear function of speed.[2] Thus the faster you run, the higher your running power is (Fig. 2).

This is good news as changes in running power on flat surfaces are almost entirely explained by changes in speed. However, an instrumented force platform that is long enough to run on is required to yield the relation between speed and running power.

Cavagna's work included running on a flat surface at constant speed. In reality, the constant speed assumption is probably often correct, but the flat surface assumption might be an understatement in many cases. Thus the added (or subtracted) effect due to slope must also be considered.

Running uphill increases running power due to increased work of hip muscles.[3] The net effect of slope has been studied by Minetti's group. Their main findings were that running uphill increases running power curvilinearly, whereas downhill running power is a U-shaped curve with the minimum at around -20% slope.[4]

Since accelerating is mechanically similar to running uphill, the information about the effects of slope on running power can be used to compensate for the effects of acceleration and deceleration.[5] Althought this is unlikely to have any measurable effect on endurance running power, it may be important for intermittent running sports such as soccer or basketball.

Principle of Polar Running Power is displayed in Fig. 1. The three inputs, which are speed, acceleration, and slope, are measured in real-time and converted to running power based on experimental data, just as previously described.

4 Validity

Polar Running Power was validated by recruiting twenty-one subjects who completed 221 runs at varying speeds (range: 2.5–9.5 m/s) across a 10 m force platform. Determination of power followed the procedures set by Cavagna.[1] To analyse the relation between power and speed, we randomly extracted ten subjects from the set. The acquired relation (Fig. 2) was then used to calculate estimated running power for the 11 remaining subjects. Finally, estimated and measured powers were compared. Mean bias, standard error of the estimate and linear correlation coefficient (r) were -0.12 W/kg (-2.2%), 0.41 W/kg (7.6%) and 0.98, respectively. Percentage values are calculated based on mean power of all runs (5.4 W/kg). The r-squared value ($r^2 = 0.96$) indicates that 96% of the variation in power was explained by the algorithm.

Polar Running Power

Polar Research and Technology

Jul 17, 2018

The process to analyse test-retest reliability of running power is ongoing at the time this paper was written and will be published in later revisions.

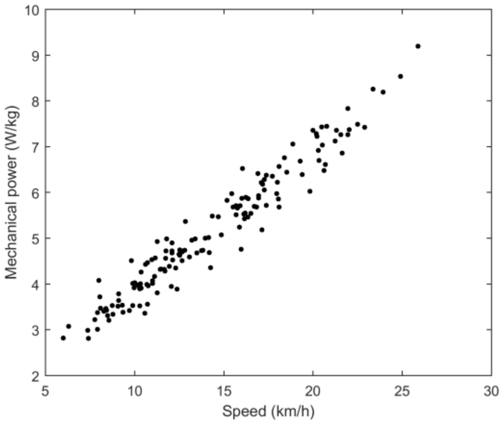

Figure 2. Relation between mechanical power and speed on flat surface at constant speed (Polar validation data).

5 Benefits

Compared to heart rate running power has a much wider dynamic range. This is due to the fact that heart rate covers only aerobic power range whereas running power extends power metering to include also anaerobic power. As a result, maximal power is at least twice as high as maximal aerobic power (Fig 3).

Due to high dynamic range, power is well suited for interval type of training. Fast response time is also a significant benefit of running power. It may take several minutes for heart rate to reach steady state, but power responds to increase in intensity almost instantaneously.

Running power does not replace heart rate; rather, they complement each other. Where heart rate can be considered an internal work rate, running power can be considered an external work rate. Thus the higher the ratio of external to internal work rate, the higher the aerobic fitness the runner has. This is automatically calculated in **Polar Running Index**.

The last benefit of running power is related to training load. Running causes musculoskeletal stress, which is often quantified by distance. However, the distance approach may be compromised if the running trail passes through terrain that has a lot of altitude variations. As a solution, Polar uses running power to derive **Muscle load**, which is a useful indicator of musculoskeletal stress independent of heart rate.

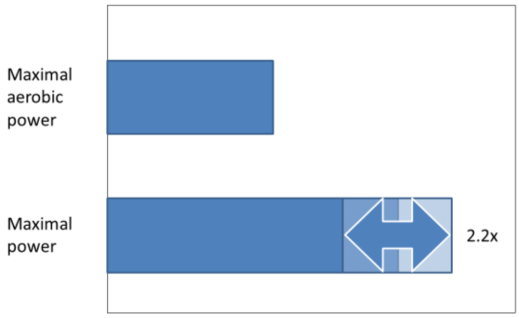

Figure 3. Comparison of maximal aerobic and maximal power.

6 Limitations

The current version of Polar Running Power does not support indoor tracking. This is because devices requires GPS to accurately determine speed and slope.

7 References

1. Cavagna, G. A. 1975. “Force Platforms as Ergometers.” *Journal of Applied Physiology* 39 (1): 174–79.
2. Cavagna, G. A., and M. Kaneko. 1977. “Mechanical Work and Efficiency in Level Walking and Running.” *The Journal of Physiology* 268 (2): 467–81.
3. Roberts, T. J., and R. A. Belliveau. 2005. “Sources of Mechanical Power for Uphill Running in Humans.” *The Journal of Experimental Biology* 208 (Pt 10): 1963–70.
4. Minetti, A. E., C. Moia, G. S. Roi, D. Susta, and G. Ferretti. 2002. “Energy

Cost of Walking and Running at Extreme Uphill and Downhill Slopes.” *Journal of Applied Physiology* 93 (3): 1039–46.

5. Prampero, P. E. di, S. Fusi, L. Sepulcri, J. B. Morin, A. Belli, and G. Antonutto. 2005. “Sprint Running: A New Energetic Approach” *The Journal of Experimental Biology* 208 (Pt 14): 2809–16.