Evaluation of mechanical workload using a GPS-tracking device

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1. Introduction

Running while accelerating/decelerating on flat terrain has been documented to be similar to uphill/downhill running at a constant speed (Di Prampero et al. 2005). As such, the values of energy expenditure obtained during running on an incline approximate those of the energy expenditure during an acceleration (di Prampero et al. 2015). In spite of numerous simplifying assumptions, these authors estimate energy cost, metabolic power requirement and actual O2 consumption ($\dot{V}O2$), based on the time variation of running speed.

While this method can yield useful information on the metabolic cost, it does not reflect the mechanical workload, a variable more closely related to muscle damage, which could provide key performance data to manage during sports practice. Indeed, the metabolic cost during an eccentric muscle contraction is about four times lower than a concentric muscle contraction (Abbott et al. 1952). However, while these deceleration phases are not harmful from a metabolic point of view, they generate greater muscle damage.

Therefore, based on the documented similarities between the biomechanics and mechanical work of accelerated/decelerated running on flat terrain and uphill/downhill running at constant speed (Mesquita et al. 2020), we develop here a new algorithm estimating the instantaneous mechanical workload based on the fore-aft speed variations. By monitoring an athlete's accelerative/decelerative phases during their activity, we estimated the positive and negative mechanical work of the centre of mass (CoM) based on published data of slope running.

2. Methods

2.1. Experimental approach of the problem

The present study was designed in two parts. Firstly, the positive, negative and net mechanical work of slope running were estimated based on data from Dewolf et al. (2016). Their subjects were average runners without particular running experience (age: 31.8 ± 8.3 years, mass: 68.8 ± 10.2 kg, height: 1.78 ± 0.07 m). They ran on an instrumented treadmill at 10 constant speeds ranging from 8 to 20 km h^{-1}, on slopes of 0, ±3°, ±6°, ±9° of inclination and their mechanical work was calculated *via* the ground reaction forces at 1000Hz. Secondly, using the equivalent slope calculations of di Prampero et al. (2005), the positive/negative and net mechanical work as well as the instantaneous positive and negative mechanical power were approximated on subjects running on level ground with a varying speed.

2.2. Estimation of W^+_{com}, W^-_{com} for slopes steeper than experimental data used in slope running

The positive and negative increments of the work done to move the CoM over one metre normalised by body mass (W^+_{com}, W^-_{com} in J kg^{-1} m^{-1}) were calculated for each subject in Dewolf et al. (2016). When running uphill/downhill, the net work done (W_{net}) over one metre corresponds to the minimum vertical work necessary for the subject overcome the slope, it is only dependent on the inclination (α), of the terrain in degrees (di Prampero et al. 2005)

$$W_{\mathrm{net}} = \left|W^+_{\mathrm{com}}\right| - \left|W^-_{\mathrm{com}}\right|$$

An exponential regression was applied to both measured W^+_{com} and W^-_{com} variables to calculate theoretical values of each work increment done ats higher/lower slopes than the ones analysed in the study, *i.e.* in slopes greater than ±9°. These exponential curves were (Figure 1A):

$$W^+_{\mathrm{com}} = 1.265e^{(0.0562\alpha)} + (-0.0118\ v + 0.1539),$$

$$\text{and } W^-_{\mathrm{com}} = 1.1829e^{(-0.081\alpha)} + (-0.0102\ v + \ 0.1344),$$

where v is the running speed. Both the regressions have a r $\geq$ 0.97. These regressions allow us to estimate values for all of the slopes which go beyond Dewolf et al.'s (2016) study (Figure 1B).

2.3. Estimation of positive/negative work increments for athletes in real time

Based on the accelerative data of a subject and the calculations of di Prampero et al. (2005),

$$W_{\mathrm{net}} = g\tan\alpha.$$

As W^+_{com} tends towards zero as negative slopes increase (Figure 1A), when the athlete was on a negative slope the W^+_{com} values were estimated from the regression of the negative slopes and W^-_{CoM} was then estimated as $W^-_{\mathrm{CoM}} = W_{\mathrm{net}} - W^+_{\mathrm{CoM}}$. The contrary was done for W^-_{com}.

The CoM power (W kg^{-1}) was estimated as the work divided by the running speed. In addition, the

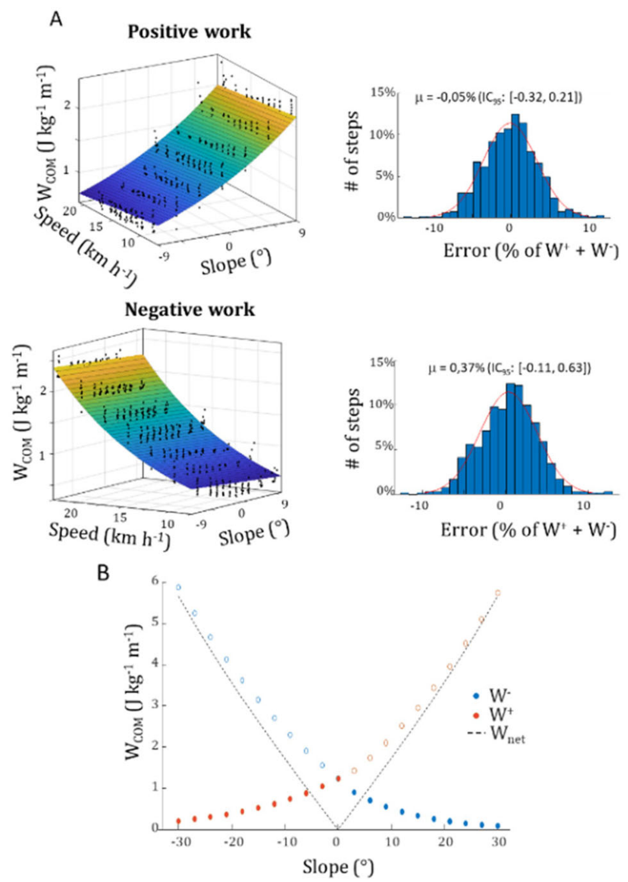

Figure 1. ***A*** Multiple regression and W^+_{com} and W^-_{com} (left) and the histograms of the errors between actual and the regression curves (right). ***B*** extrapolation of W^+_{com} and W^-_{com} based on the regression fit.

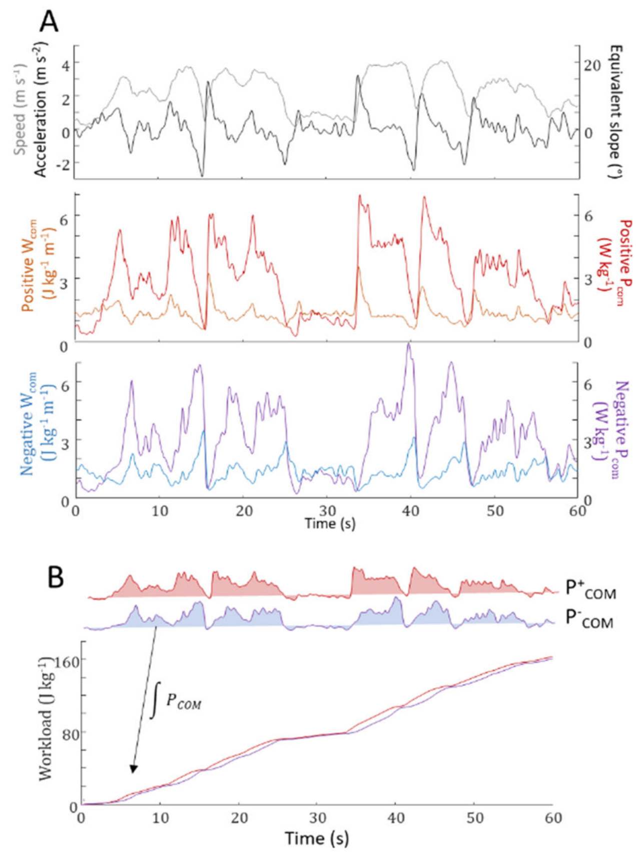

Figure 2. An example of a running session of 30 s. ***A*** from top to bottom: speed (grey) and acceleration (black); extrapolation of the W^+_{com} and P^+_{com}; extrapolation of the W^-_{com} and P^+_{com}. ***B*** total positive (red) and negative (blue) workload over the running session.

workload over a period may be evaluated as the time integral of the power curve.

3. Results and discussion

In order to evaluate the accuracy of the regression curves, we evaluated the difference between the measured positive work and W^+_{com} and the difference between the measured negative mechanical work and W^-_{com}. From $-9°$ to $+9°$, the error that is being made between the regression and the experimental data is on average $-0.4 \pm 3.0\%$ for W^+_{com} and $-0.3 \pm 3.5\%$ for W^-_{com}, (Figure 1A – right panels). Furthermore, the error measured by the ratio between the difference of the measured data and the estimation over the measured total work (sum of positive and negative work increments) is most of the time below ±5%.

Although the tracking of different data during training sessions and matches is not novel, the extrapolation of this data to obtain work and power values is. Such information is useful as it gives insight into the power required to accelerate and brake the movements of the CoM. This is useful as the power required to brake the CoM (*i.e.* eccentric muscle contractions) is up to four times higher than the metabolic cost (Abbott et al. 1952). Therefore, such data can shed light on high intensity phases done positively (concentrically) and negatively (eccentrically) during a session, which in turn could be indicative of the kind stress the subject is performing.

Indeed, such an approach brings insight into (1) the magnitude of positive and negative mechanical power being done to move the CoM, related to muscle stress. Also, by computing the workload over a period of time (Figure 2B) the algorithm also brings insight into (2) the quantity of positive/negative work that the subject is doing over a training, related to muscle fatigue.

4. Conclusions

Estimation of work, power, and workload is not only useful for a better follow-up in training sessions and in-game but also as a potential comeback from injury marker, as eccentric contractions generate more muscle damage than concentric contractions. Future research should focus on relating our findings to muscular fatigue variables such as creatine kinase values and muscular fatigue in other team sports.

Disclosure statement

No potential conflict of interest was reported by the authors.

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