What is running economy? A clinician's guide to key concepts, applications and myths

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Running economy is one of the key physiological predictors of distance running performance[1] and articles about running economy are abundant in the scientific and lay communities. Clinicians regularly encounter coaches and athletes aiming to improve performance and may also recommend injury-related interventions which influence running economy, and therefore should have a firm understanding of running economy. However, running economy is often misunderstood and measured in an inconsistent or unjustified manner. As such, it can be difficult to make sense of the literature regarding how demographics, biomechanics (eg, stride rate, footstrike) and interventions (eg, footwear, orthoses, biomechanical alterations, training programmes) influence running economy, thus performance. Here, I address five critical questions about running economy so that existing research can be interpreted appropriately and clinicians can accurately advise athletes. Additionally, the online supplementary appendix provides further relevant concepts and examples to demonstrate these points.

WHAT IS RUNNING ECONOMY AND HOW IS IT MEASURED?

Running economy is defined as the aerobic demands of running, or the relationship between oxygen consumption (VO_2: expressed in units of L O_2/min or mL O_2/kg/min) and running speed.[2] In trained runners with similar maximal aerobic capacity (VO_{2max}), those with superior running economy (lower VO_2 per unit distance: mL O_2/kg/km) achieve faster racing times[2] due to reduced metabolic demand at submaximal intensities. Likewise, excellent running economy may compensate for VO_{2max} limitations, even at the elite level[1] where athletes may have reached their individual physiological boundaries.

Running economy is typically measured using a motorised treadmill, using a protocol that allows individuals to run at progressively faster speeds, while steady-state VO_2 is measured using a metabolic cart. Running economy may also be measured on a running track using a portable metabolic cart. A variety of measurement protocols exist, but generally 3–6 min stages are used (to ensure that a steady-state is reached), with equal rest intervals between stages. Following the final stage of the running economy test, a VO_{2max} test can be performed. The combination of submaximal and maximal VO_2 data allows one to determine relative intensity of various race paces (ie, the percentage of VO_{2max} one achieves for a given running speed). Blood may also be collected during these tests to determine lactate threshold. Together, data from these measurements can be used to monitor an athlete's aerobic profile, evaluate or validate acute and chronic responses to various training and clinical interventions, and compare individuals and groups of athletes.

DO INJURY-RELATED INTERVENTIONS INFLUENCE RUNNING ECONOMY?

Biomechanical and footwear alterations are commonly recommended for reducing injury risk, so clinicians should consider their influence on running economy in competitive athletes. For instance, intentionally increasing stride frequency to 95 steps/min results in the lowest breaking forces, impact peaks and vertical loading rates, but the poorest running economy.[3] There remains debate over the utility of minimalist and barefoot shoes for long-term injury prevention,[4 5] thus running economy should not be the major determinant in shoe selection, except perhaps for competition. For example, minimalist shoes were more economical than traditional shoes for level running at one speed in a non-fatigued state, but resulted in greater calf pain following an intense trail run (and the running economy advantage was also lost post-run completion).[6] Likewise, methodological differences and population specificity make it difficult to determine how in-shoe orthoses influence running economy.[7] Clinicians can inform concerned athletes and coaches that interventions which potentially impair running economy may still provide a more favourable solution than chronic injury which precludes optimal training and competition.

SHOULD NON-COMPETITIVE RUNNERS ATTEMPT TO IMPROVE RUNNING ECONOMY?

Although the literature typically describes reductions in VO_2 at a given speed as 'improved' running economy, this is not necessarily desirable for recreational athletes who simply run for fitness, rather than performance. Interventions which decrease oxygen use at a given speed signify that exercise intensity is reduced, and fewer calories are consumed, which may actually oppose the goals of fitness-focused recreational runners. Thus, non-competitive individuals need not focus on 'improving' running economy, as investing resources into other interventions (eg, injury prevention, strength training) may be more relevant to their health/fitness goals.

DOES RUNNING ECONOMY VARY WITH RUNNING SPEED?

Many studies examine running economy at typical easy training paces, but competitive runners do not need to optimise running economy at those speeds, unless they are competing in very long-duration events (ie, ultramarathons). Since running economy is related to racing performance, it should be measured at speeds similar to those of competition, otherwise inaccurate conclusions may be drawn.[2] For instance, Daniels demonstrated that elite male marathoners were more economical than other elite distance runners at one training pace, but had equal economy at marathon race pace.[2] Thus, it cannot be assumed that running economy at a slow pace is representative of running economy at a much faster pace. Specific examples which demonstrate the value of using multiple, race-specific test speeds are found in the online supplementary appendix.

Daniels provides numerous examples of how running economy may seem identical or different between groups, depending on the treadmill speed. Through elegant analysis, they conclude "the range of velocities over which runners are tested can determine whether it is concluded that one runner, or type of runner, has an economy advantage over another…. At common test speeds, just about any conclusion can be reached relative to running economy comparisons". An example of the complications that arise in comparing different levels of runners using common fixed test speeds is demonstrated using data from Beck[8] in figure 1. In this example, relative intensity data suggest the fastest speed corresponds

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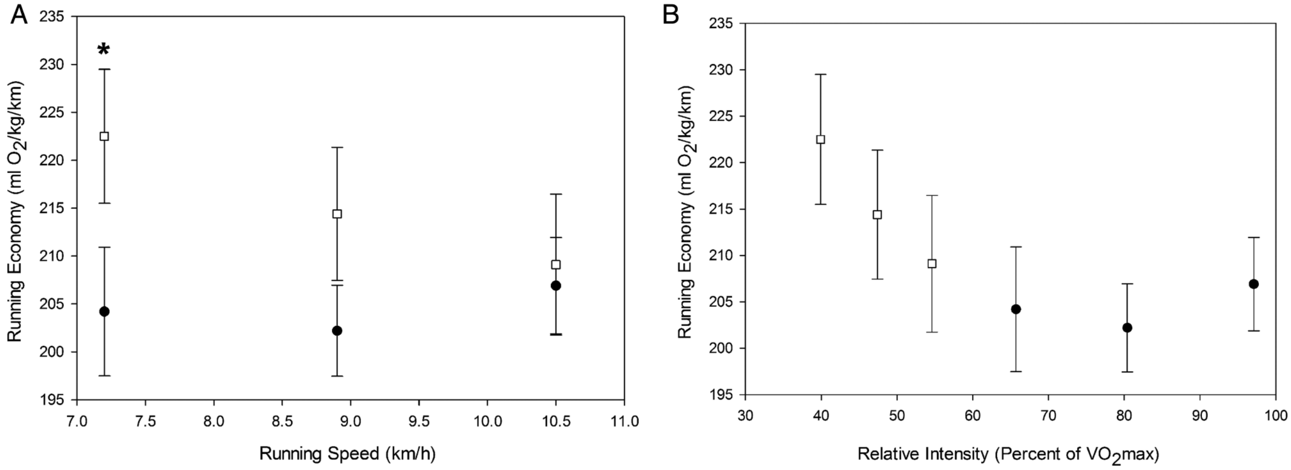

Figure 1 Differing effects of relating running speed versus relative intensity to running economy. Data comparing older (● 68.9±4.7 years) and younger (□ 21.3±2.7 years) runners at three fixed speeds are used to demonstrate that the quantification of intensity (absolute speed vs percent of VO_{2max}) can lead to different conclusions regarding running economy. Bars represent computed SE. * indicates statistical significance between groups. (A) When absolute treadmill speed is used for comparison, older runners have superior running economy at the slowest speed, and no significant differences exist at the two faster speeds. From this comparison, the study's authors concluded that older runners retain 'youthful' running economy. (B) When relative intensity is computed from reported VO_{2max} values (young: 56.1; old 37.3 mL O_2/kg/min), it becomes clear that the fixed speeds studied resulted in very different relative intensities between groups which preclude meaningful group comparisons and consequent performance implications. VO_{2max}, maximal consumption of oxygen.

to 5K (or shorter) race effort in the older athletes (which was sufficiently strenuous to prevent some from completing the protocol), yet easy training run effort (or slower) in the young athletes.[9] Thus, when comparing runners of different fitness levels, measurements at similar relative intensities may provide more useful information than measurements at common speeds.

WHAT CONFOUNDING FACTORS COMPLICATE INTERPRETATION OF RUNNING ECONOMY?

Numerous factors influence running economy and must be considered in clinically interpreting data from the literature and individual tests, and some specific examples are found in the online supplementary appendix. Running surface (ie, treadmill vs overground), surface gradient and wind resistance all influence running economy. Additionally, some daily fluctuation in running economy occurs and therefore one must be careful in differentiating between normal expected variation and real changes in running economy. Although many studies examine how a given intervention acutely influences running economy, these short-term changes do not necessarily reflect long-term habituation to that intervention. Since running economy often is normalised to body mass, this should be accounted for when interpreting running economy data. It is also important to realise that findings from studies in recreational individuals may not translate to well-trained/elite competitive athletes, who may have less margin for improvement in running economy due to differences in training, body composition, physiological capabilities and biomechanics.

SUMMARY

Running economy measurements can be valuable for evaluating running-specific physiology and the effects of various interventions, but they ultimately must be applicable to racing performance. Since running economy does vary within an individual across speeds and surfaces and is affected by numerous confounding factors, test protocols should be specific to the population and environment of interest, and extreme caution is warranted in interpreting running economy data collected at speeds below race paces and from non-competitive runners. Numerous other factors also influence running economy and must be taken into consideration when interpreting data from individual athletes and the scientific literature. Therefore, clinicians should carefully consider the methodology used in running economy studies before making recommendations to coaches and athletes.

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