Abstract

Purpose: The hyperbolic distance-time relationship can be used to profile running performance and establish critical speed (CS) and D'. Typically, to establish these parameters multiple (3+) performance trials are required, which can be highly fatiguing and limit the usability of such protocols in a single training session. This study aimed to compare CS and D' calculated from a two-trial (2-point model) and a three-trial (3-point model) method.

Methods: 14 male distance runners completed three fixed-distance (3600, 2400, 1200 m) time trials on a 400 m outdoor running track, separated by a 30-minute recovery. Participants completed the protocol nine times across a twelve-month period, with approximately 42-days between each test. CS and D' were calculated using all three distances (3-point model) and also using the 3600 and 1200 m distances only (2-point model).

Results: Mean (±SD) CS for both 3-point and 2-point models was 4.94 ± 0.32 $m.s^{-1}$, whilst D' was 123.3 ± 57.70 m and 127.4 ± 57.34 m for 3-point and 2-point models, respectively. Overall bias for both CS and D' between 3-point and 2-point model was classed as trivial.

Conclusions: A 2-point time-trial model can be used to calculate CS and D' as proficiently as a 3-point model, making it a less fatiguing, inexpensive and applicable method for coaches, practitioners and athletes to monitor running performance in one training session.

Introduction

Human physiology in linear energetics can be characterised by the hyperbolic power-duration relationship.[1,2] Much of the literature in this area has been focused in cycling using power measurements as it is controlled, accurate, negates environmental conditions and the mechanical output is purely physiological.[3,4]A similar relationship is observed between distance and time in association with velocity in running.[5] The running based parameters of the distance-time relationship are termed critical speed (CS) and D'. CS has been described as the highest sustainable running speed that can be maintained without a continual rise in VO_2. [6] It has been reported to demarcate the boundary between the heavy and severe exercise intensity domains and is correlated with maximum lactate steady state and VO_{2max}.[3,4,7] D' has been described as a mainly anaerobic parameter, comprising of energy derived through substrate-level phosphorylation using PCr and glycogen, with an additional small aerobic contribution from myoglobin- and (venous) haemoglobin-bound O_2 stores.[6] In the running paradigm, D' is the distance that can be covered above CS intensity.

Hughson and colleagues [5] originally demonstrated the distance-time relationship in running using a constant velocity treadmill protocol, to elicit a time to exhaustion (TTE) at various speeds. TTE protocols have been commonplace in the literature to calculate CS and D', with multiple (3+) trials performed at least 24 hours apart. [5,7] Recently, Galbraith et al. validated a fixed distance field-based protocol using a competition standard 400 m athletics track, thereby improving the ecological validity of the test.[8] This new protocol has the additional benefit of being performed in a single session by reducing the recovery time to 30 minutes and the number of performance trials to three. In cycling, Parker Simpson and Kordi [9] further added to this concept, showing that once participants were fully familiarised, only two maximum time-trials that were three and twelve minutes in duration were required to produce valid and reliable values for critical power (CP) and W' (the cycling equivalent of CS and D', respectively). A single visit test for CS and D', as demonstrated by Galbraith and colleagues [8] is a practical advancement from the multiple-visit TTE treadmill protocols. However, three exhaustive time-trials, interspersed with recovery, could still be considered a time-consuming, intensive and fatiguing protocol for an athlete, making coaches more hesitant to prescribe the protocol. It would be advantageous if CS and D' could be determined with fewer efforts (i.e. two time-trials), making the protocol more appealing to coaches and athletes. Whilst two time-trials have produced valid and reliable values for CP and W' in cycling [9], it cannot be assumed the same relationship will hold true in running, as the mechanics of movement differ (i.e. includes eccentric and concentric phases of muscle contraction), cadence/foot speed are not controlled for and power cannot be accurately and reliably measured [10]. This means that speed is the measure of interest. However, speed is the summation of propulsion (mechanical power output) against resistance (running resistance and air resistance), which are heavily influenced by environmental conditions. Furthermore, if CS and D' can be measured in two time-trials within one training session, it would make it easier to asses running physiology and performance in the athletes ecological environment, as previously reported with cycling.[9] Lastly, being able to perform fewer maximal time trials will be less fatiguing to the athletes, making a 2-trial protocol a more viable option should a coach, athlete or practitioner want to monitor CS and D' longitudinally.

Therefore, the purpose of the present study was to determine whether a 2-trial protocol gave equivalent values for CS and D' to a 3-trial protocol. It was hypothesized that the removal of the middle distance would not alter CS and D'.

Methodology

Participants

Fourteen male distance runners (mean ± SD age 28 ± 8 years, body mass 67.0 ± 6.3 kg, VO_{2max} 69.8 ± 6.3 $ml\cdot kg^{-1}\cdot min^{-1}$, training history 11 ± 2 years) were recruited from local athletics clubs. Participants provided written informed consent for this study that had been approved by The University of Kent ethics committee.

Procedure

The dataset used for this study was originally collected and reported in Galbraith et al. (2014) and has been reanalysed in order to report the data for this study.[11] Each participant completed three fixed-distance (3600, 2400, 1200 m) time-trials on a 400 m outdoor running track. Trials were conducted in the order of longest to shortest, on the same day, with a 30-minute rest between trials. Finishing times were recorded to the nearest second. Following a familiarisation session, participants completed the protocol nine times across a twelve-month period, with approximately 42-days between each test. Environmental conditions were recorded at each test (mean temperature 13.8 °C [range 0–24 °C], mean wind speed 1.8 $m.s^{-1}$ [range 0.0–2.0 $m.s^{-1}$]).

A linear regression analysis was used to determine CS and D' using the linear distance-time model (R^2 range 0.99–1.00, SEE range CS 0.00–0.11 $m.s^{-1}$, D′ 0–64 m). When using the 1/t model to determine CS and D' similar results were seen (R^2 range 0.98–1.00, SEE range CS 0.00–0.15 m.s-1, D′ 0-52 m). Due to the relative ease in measuring both distance and time in an applied setting, the linear distance–time model (equation 1) was chosen as it was deemed suitable for coaches and/or practitioners to calculate CS and D' from this model. CS and D' were calculated using all three distances (3600, 2400, 1200 m; 3-point model) and also using the 3600 and 1200 m distances only (2-point model).

$D = (CS*t) + D'$ (Equation 1)

Statistical Analysis

The 3-point model was taken to be the criterion measure.[12] Accordingly, overall bias and standard error of estimate (SEE) were calculated. All validity measures were calculated using raw units and standardised. Standardised values were interpreted using the modified Cohen scale: <0.20, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0, extremely large. Coefficient of determination (R^2) was used to assess the proportion of variance explained between the 3-point and 2-point models for the CS and D', respectively. The smallest worthwhile change (SWC) was also calculated for CS and D' for both models. Data are presented as either mean (±SD) or mean (± 90% CL).

Results

Mean (±SD) of both 3-point and 2-point CS was 4.94 ± 0.32 $m.s^{-1}$, whilst D' was 123.3 ± 57.70 m and 127.4 ± 57.34 m for 3-point and 2-point models, respectively. The relationship between 3-point CS and 2-point CS and 3-point D' and 2-point D' are shown in Figure 1 (a) and (b), respectively. The 2-point model could account for 99 and 98% of the variation in CS and D', respectively.

In comparison to the 3-point CS (± 90% CL), the 2-point CS model showed an overall mean bias of 0.00 $m.s^{-1}$ (0.00 – 0.01 $m.s^{-1}$) and 0.00 (0.00 – 0.00) when standardised, which equates to a trivial bias. SEE was 0.00 $m.s^{-1}$ (0.0%) (0.00 – 0.01 $m.s^{-1}$) and when standardised 0.02 (0.01 – 0.02).

When measuring D' (± 90% CL), the 2-point model showed an overall mean bias of 3.72 m (2.39 – 5.04 m) and when standardised 0.06 (0.04 – 0.09), which translates to a trivial bias. SEE was measured as 9.01 m (7.1%) (8.16 – 10.07 m) and 0.16 (0.14 – 0.18), which also equates to a trivial effect.

The smallest worthwhile change (SWC) in D', when using the 2-point model, was 11.61 m, compared with 11.54 m when using the 3-point model. For CS, for both 3-point and 2-point model the SWC was 0.06 $m.s^{-1}$.

Discussion

The principle finding of this study was that a 2-point model can be used to calculate critical speed and D' as proficiently as a 3-point model, with minimal overall bias or error, in experienced, highly-trained runners. The 3-point model, and other methods for the determination of the speed-time relationship can be performed in one session. The 2-point model, however, might increase the likelihood/willingness of a coach/athlete to incorporate CS/D' determination into the training schedule. These two key points increase the practicality for the determination of the speed-time relationship, increasing the likelihood of coaches, practitioners and athletes incorporating the protocol into their training/monitoring programme.

When measuring critical power and W', Parker Simpson and Kordi compared a 3-point and 2-point time-trial model and showed that once familiarised, a 2-point time trial model mirrored the CP and W' of a 3-point time trial model.[9] A single all-out trial of 3-minutes in duration has also been used to estimate CP and W' in cycling [13] and CS and D' in running [14], demonstrating promising time benefits over longer duration protocols. The present study reports similar data for CS and D' in running exercise, where once familiarised, the 2-point model mirrored the CS and D' of a 3-point model, with minimal overall bias or error.

The SEE is recognised as an important parameter to estimate the quality of the regression model. Previous research has suggested an upper SEE limit for CS/CP of 2% and 10% for D'/W'.[15] The SEE of the regression model may be reduced when more trials (data points) are included in the model. Consequently, when using a 3-point model, it has been suggested that a fourth or fifth prediction trial should be added when the SEE exceeds these limits.[16] However, adding additional trials (or needing to repeat trials) would lower the ecological validity and overall usability of the single-visit testing method, as well as making it highly fatiguing and therefore less appealing for athletes or coaches. It is acknowledged that the SEE for D' in the current study exceeded the recommended limits on occasion, therefore adding a fourth predictive trial may have improved the fit of the regression model in these instances. Notwithstanding the time saving benefits of the 2-point model, there are advantages to using a single visit 3-point model. Recent research has demonstrated that a 3-point model did not impact the fit of the regression by increasing SEE above the accepted limits. [17] Furthermore, there is a growing body of evidence that suggests using a single visit 3-point TT model is more reliable and ecologically valid, when determining CP/CS, in comparison to TTE trials.[8,15,18] Finally, a 3-point model provides coaches and practitioners with SEE values, an important measure in assessing the quality of the model and therefore, if possible, a single visit 3-point model is recommended.[19]

CS appears to be a reliable and robust parameter with a high level of agreement when transferred from a laboratory to a field setting.[8,19] D' however, has been reported to be less reliable between repeated tests [20] and has shown a lower level of agreement between laboratory and field protocols. [17] The current study reports similar values for D' from a 3-point and a 2-point model, with minimal overall bias or error.

Practical Applications

The 2-point model reflects the same outcomes for CS and D' as the 3-point model, however it is not possible to establish the quality of the regression using the 2-point model. Notwithstanding the limitations, the current study demonstrates that the CS and D' from the 2-point model are robust, closely matching that of the 3-point model. Due to the time-efficient protocol, the 2-point model is more likely to be employed in an applied setting (i.e. one training session) making it more usable for coaches, practitioners and athletes to monitor CS and D'.

Conclusion

A 2-point time-trial model can be used to calculate CS and D' as proficiently as a 3-point model, making it a less fatiguing, suitable, time-efficient and applicable method for coaches and practitioners to monitor running performance in well-trained athletes.

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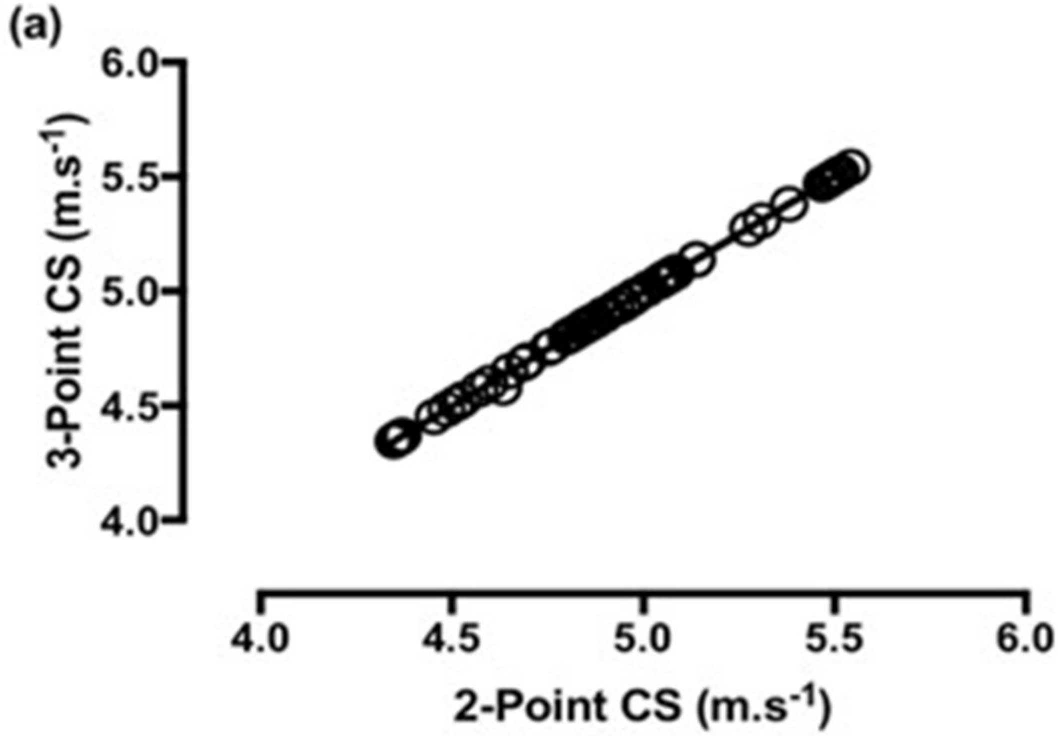

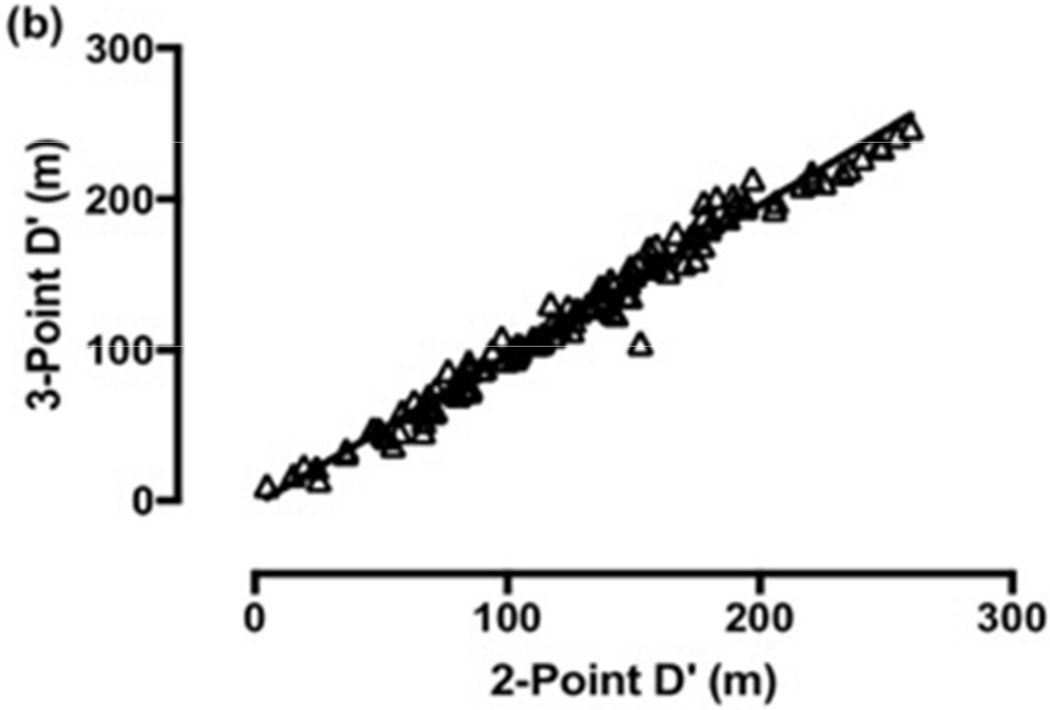

Figure 1 (a): Relationship between critical speed derived from 3-point and 2-point fixed distance time-trials. R2 = 0.99, y = x - 0.01; (b) Relationship between D' derived from 3-point and 2-point fixed distance time-trials. R2 = 0.98, y = 0.99x + 2.94.