Running Performance can be Predicted by Log v-Log t-Models based on Non-Exhaustive Tests and Rating of Perceived Exertion

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Abstract

Individual running performances at different distances can be described by log v-log t-models. The study tests, if rating of perceived exertion while submaximal graded exercise (GXT) and constant load test (CLT) can be used for parameter estimation of log-log-models so that running performance can be predicted. Under laboratory and field conditions 13 and 12 subjects performed a submaximal GXT and CLT, where RPE was measured using RPE15-Scale (Borg, 2004) to calculate 3000m running-performance. Finally, maximal 3000m track runs were done for model verification. Predicted and measured running speed were highly correlated ($r = .92$ vs. $r = .96$, $p < .001$). In the laboratory study predicted speeds were significant lower than measured speeds, whereas by field tests predicted values didn´t differ from measured ones. It is concluded that the presented approach offers an accurate, economic and non-exhaustive possibility of performance prediction in running.

Key words

log-log-model, rating of perceived exertion, performance prediction, running, submaximal exercise test

Introduction

One purpose of laboratory and field testing in sports and exercise is to predict future performance to optimize training or pacing strategies. Measuring maximal oxygen consumption (VO_2max) and lactate threshold (LT) are viewed to be the gold standard in performance prediction as these variables are highly correlated to exercise performance, especially in endurance sports (Kindermann, 2004; Scharhag-Rosenberger, & Schommer, 2013). From an economical point of view such tests need financial and technical resources not every athlete can afford to. From a theoretical point of view there is no direct link between VO_2max or LT and endurance performance, so it remains unclear how long a certain velocity or power could be maintained by a single athlete, even when VO_2max and LT are known. Therefor predicting exercise performance is only possible on the additional basis of statistical models bridging the gap between physiological measurements and exercise performance. Because such models usually come from cross-sectional studies their predictive validity and accuracy is uncertain in single case. For this reasons past performances are often the best estimates of future performance.

As time to exhaustion is systematically decreasing with increasing power-output past performances can be used to predict performances at even other distances if the individual power-time to exhaustion-relationship is known. Grosse-Lordemann and Müller (1936) and Müller (1938) have shown that there is a linear relationship between logarithmized power (log N) and logarithmized time to exhaustion (log t) for exhaustive cycling at different constant loads. According to the authors individual power-time-dependencies can be described by the following equation:

(1) log t = b + a * log N

So-called log-log models can also be applied to running, so that velocity-time relationship can be modelled in a similar way (Billat, Koralsztein, & Morton, 1999; Frederick, 1959; Hinckson, & Hopkins, 2005):

(2) log v = c + k * log t

As this relationship is determined by just two parameters, measurements of time to exhaustion for only two different velocities should allow parameter estimation. However, measuring time to exhaustion is strenuous and, in some cases, impossible. Several authors have shown that submaximal graded exercise tests (GXT) and non-exhaustive constant load tests (CLT) can be used to determine maximal speed and time to exhaustion, respectively, using rating of perceived exertion and extrapolating to the point of maximal exertion (Borg, 1998; Faulkner, & Eston, 2008; Faulkner, Parfitt, & Eston, 2008; Noakes, Snow, & Febbraio, 2004). To my knowledge such submaximal exercise tests haven´t been used for estimation of individual velocity-time to exhaustion-relationships and further performance prediction, yet. The main issue of the two present studies is to examine whether two submaximal exercise tests allow performance prediction in running using rating of perceived exertion and log-log-performance models. Special aims are twofold: Study 1 tests the log-log model in combination with submaximal laboratory testing, whereas study 2 examines, whether perceptually driven, submaximal field tests are suitable for parameter estimation and performance prediction.

Methods

Study 1

Subjects

13 male students of sports science (age: 25±1.4y; height: 183±5cm; weight: 86±8kg) participated voluntarily in the study after having been introduced into design and methods. All of them were training regularly but had no former experience in rating of perceived exertion using Borg scale or similar scales.

Design

Participants visited the laboratory two times at intervals of one week to perform a graded exercise test (GXT) at the first visit and a constant load test (CLT) at the second visit. For both tests a treadmill (Woodway PPS med) with a grade of 1% was used. One week later a 3000m competition was carried out on the track. Subjects were told not to train the day before each of the three tests and to eat normally.

Tests

The first test began with a 3min warm-up at 6kmh^{-1}. The GXT started after a break of 1min with 8kmh^{-1}. Speed increased 2kmh^{-1} every 3min with intervals of 1min between. During the last 20s of each 3min-stage the subjects were asked for their rating of perceived exertion using the German version of Borg´s RPE15-scale (Borg, 2004). The test was terminated after having reached RPE of 17 or higher. Linear regression models were used to determine the velocity corresponding to the RPE of 16 for every single athlete ($v_{GXT-RPE16}$). $v_{GXT-RPE16}$ was used as speed for the constant load test after 3min of warm-up at 6kmh^{-1}. Every 3min subjects were asked for their rating of perceived exertion. The test was terminated after having reached either the RPE of 18 or after having run for 18min at $v_{GXT-RPE16}$.

Data processing

For every subject data from GXT was used to fit individual regression models with RPE as dependent and speed as independent variable. By extrapolating to RPE of 20 $v_{GXT-RPE20}$ was calculated (Fig. 1-1). $v_{GXT-RPE20}$ estimates the individual speed, that can be maintained for 3 min, which represents the first data point for further performance modelling.

The second data point is calculated from individual data of CLT in a similar way by extrapolation (Fig. 1-2): Regression models from RPE to time were used to determine $t_{CLT-RPE20}$, the time when RPE of 20 should be reached. As the speed of CLT equalled $v_{GXT-RPE16}$, $t_{CLT-RPE20}$ also represents the time $v_{GXT-RPE16}$ could be kept up.

Afterwards, both data points were used to determine coefficients c and k of equation (2). By means of these individual log-log models the velocity for 3000m was

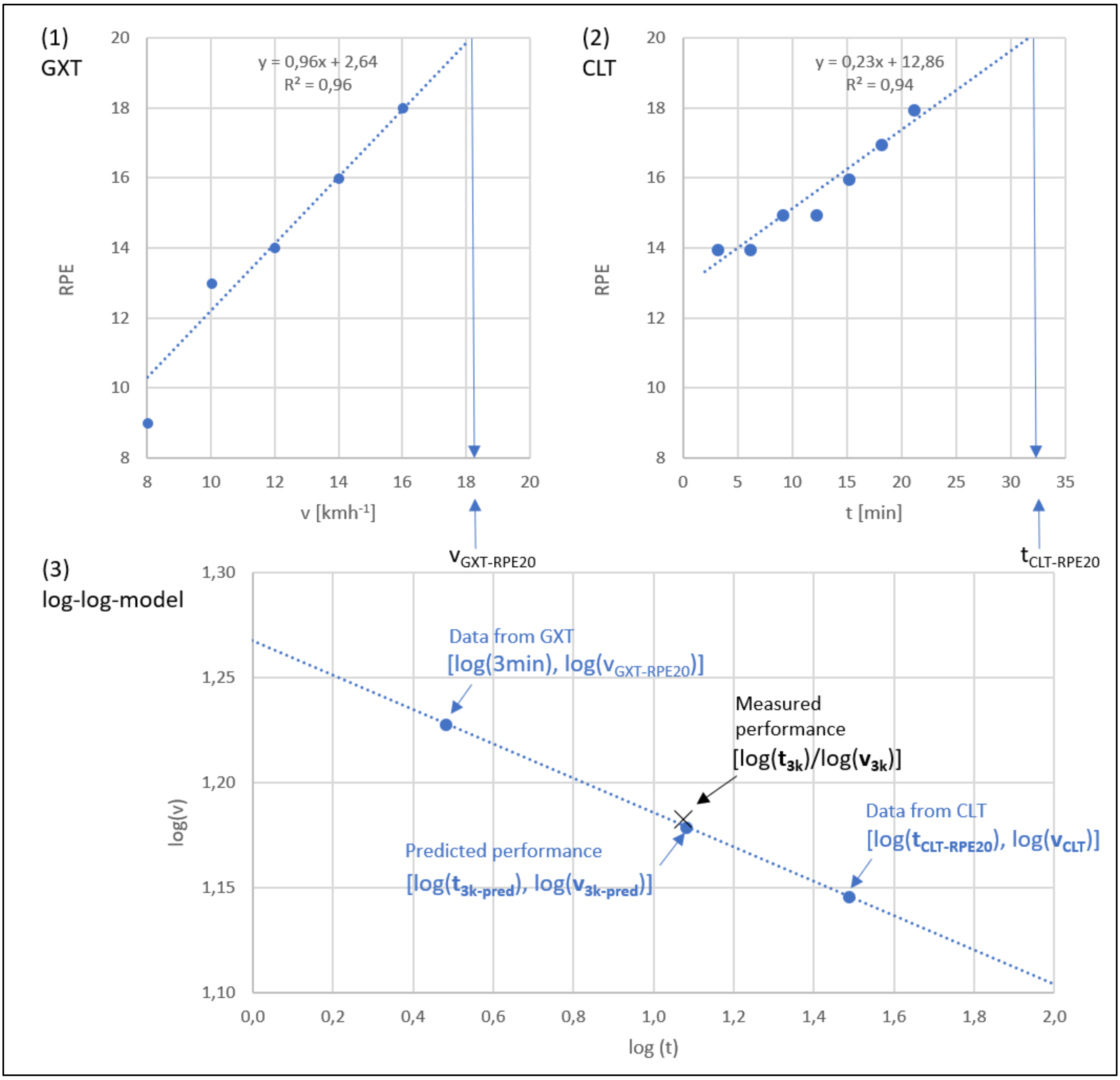

Fig. 1: Approach of performance prediction based on (1) submaximal graded exercise test (GXT) and (2) constant load test for estimation of two data points. Data points are used to determine parameters of (3) individual log v-log t-model for prediction of 3000m-running speed ($v_{3k\text{-pred}}$). Data of one representative subject of study 1 (laboratory testing) is shown. v_{3k} represents measured running speed of a maximal 3000m-track run.

predicted ($v_{3k\text{-pred}}$) (Fig. 1-3). Validity of performance prediction was evaluated by Pearson- and Intraclass Correlation-Coefficients for $v_{3k\text{-pred}}$ and velocity of 3000m-test (v_{3k}). All calculations were done by IBM® SPSS® Statistics (Version 24).

Study 2

Subjects

The second study was conducted with 12 (8 males, 4 females) voluntarily participating triathletes of a local triathlon club. The Participants with an age of 34±13y were training regularly at local and regional level.

They had no further experience using rating of perceive exertion scales.

Design

Athletes were tested on three different days with intervals of one week. On the first day a submaximal 3.2km run with constant velocity was conducted on the track after a warm-up period of 15min which was used for individual familiarization with rating of perceived exertion and perceptually regulating running speed. Afterwards, participants should start with a self-selected velocity corresponding to RPE of 15 on the first 400m lap. From then on athletes should hold this speed and were told to report rating of perceived exertion at the end of every 400m lap. Tests should be terminated if RPE of 17 or higher was reached before having finished 3.2km.

On the second day a perceptually driven GXT had to be done after 15min-warm-up. Athletes had to run three repetitions of 800m, starting with self-selected speed corresponding to RPE of 14 on the first 800m stage. From stage to stage speed should increase in a self-regulated manner but should be held constant for every single 800m-stage. Running time was measured and RPE was reported at the end of every 800m-stage.

On the last day a 3000m competition was carried out in the same way as in study 1.

Data processing

Similar as in study 1 data of GXT was used for regression analyses to calculate $v_{GXT\text{-}RPE20}$, which represents in this case the supposed maximal 800m-speed. Corresponding individual run times ($t_{GXT\text{-}RPE20}$) were calculated by simple transformations. Maximal time, for which the self-selected speed of constant load test (v_{CLT}) could be maintained, was also calculated by extrapolating to RPE of 20 using linear regression of RPE to run time ($t_{CLT\text{-}RPE20}$). Again, both data points served for parameter estimation of individual log-log-models and prediction of 3000m-speed ($v_{3k\text{-}pred}$). Further analyses followed the same scheme as described above.

Results

Study 1

Model fit for individual regression analyses ranged from r = .96 to r = .99 for GXT-data and from r = .83 to r = .99 for CLT-data. $v_{GXT\text{-}RPE20}$, representing the highest possible speed for a period of 3min, was between 13.4 and 20.8 kmh^{-1} (M = 16.6kmh^{-1}; SD = 2.0kmh^{-1}). $v_{GXT\text{-}RPE16}$, which was used for CLT, ranged from 10 to 16 kmh^{-1} (M = 12.6kmh^{-1}; SD = 1.6kmh^{-1}). Predicted $t_{CLT\text{-}RPE20}$ was M = 16.9min (SD = 6.5min) with a range of 10.3 to 30.4min.

Individual values of these variables were used for predicting 3000m-run time by individual log-log-models (for parameter estimates see tab. 1). Predicted mean 3000m-run time was M = 14.6min (SD = 2.5min; range: 10.4 to 19.8min) corresponding to a predicted speed of M = 12.7kmh^{-1} (SD = 2.1kmh^{-1}; range: 9.1 to 17.3kmh^{-1}).

Mean measured 3000m-run time (t_{3k}) ranged from 10.5 to 14.5min (M = 12.8min; SD = 1.1min) with corresponding speed (v_{3k}) of M = 14.2kmh^{-1} (SD = 1.3kmh^{-1}; range: 12.5 to 17.2kmh^{-1}).

Correlations of predicted and measured 3000m-speed were r = .88 ($p < .001$) and ICC = .54 ($p < .05$) (Fig. 2). t-test for paired samples indicated a significant difference between predicted and measured speed (M = -1.5kmh^{-1}; SD = 1.2kmh^{-1}; t_{12} = -4.55; $p < .001$). Further analyses revealed a correlation of r = .62 ($p < .05$) for $v_{GXT\text{-}RPE20}$ and v_{3k} with a mean difference of 2.4kmh^{-1} between both variables (SD = 1.6kmh^{-1}; t_{12} = 5.30; $p < .001$).

Study 2

In Study 2 model fit for individual regression analyses were similar and ranged from r = .91 to r = 1.00 for GXT-data and from r = .84 to r = .95 for CLT-data. $v_{GXT\text{-}RPE20}$, here representing the highest possible speed for 800m, was between 10.2 and 20.5kmh^{-1} (M = 14.6kmh^{-1}; SD = 3.5 kmh^{-1}).

Tab. 1: Parameters c and k of log-log-models (log v = c + k * log t) for laboratory (study 1) and field testing (study 2) [M ± SD]

Parameter	Study 1	Study 2
c	1.30 ± 0.06	1.18 ± 0.10
k	-0.17 ± 0.06	- 0.06 ± 0.03

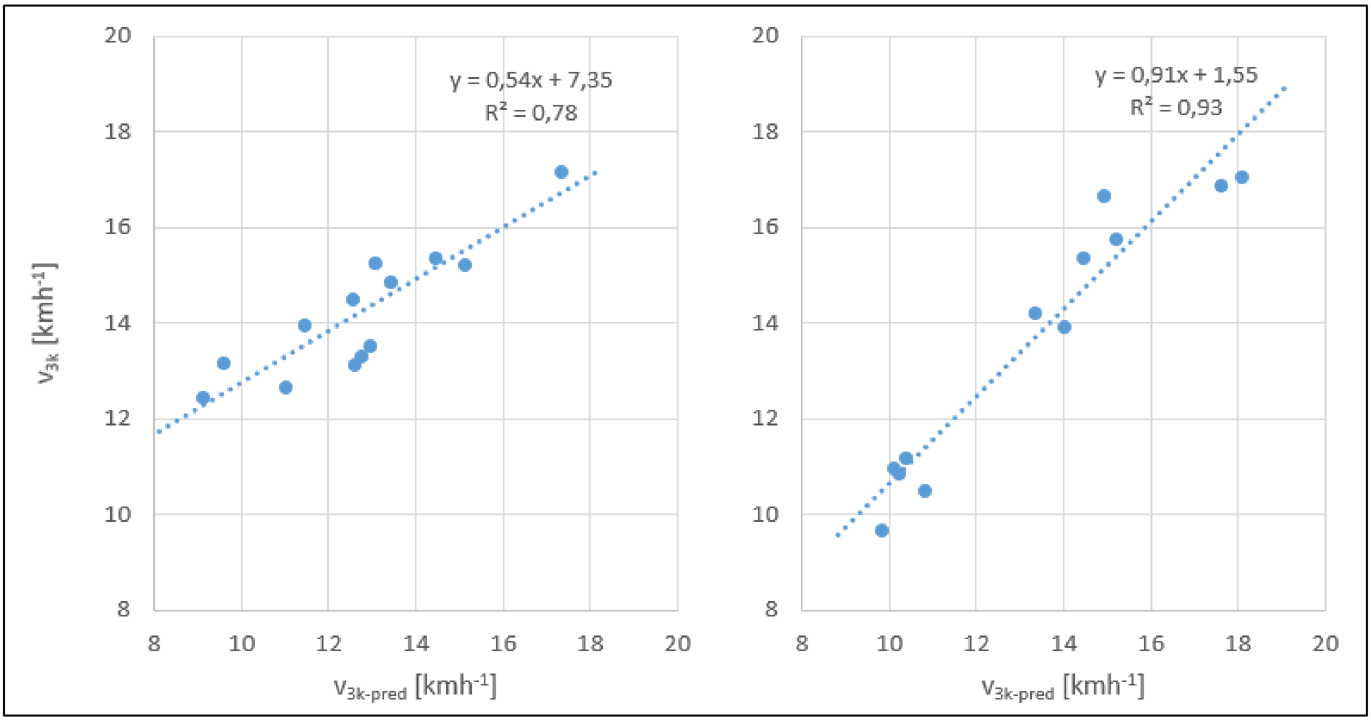

Fig. 2: Predicted ($v_{3k\text{-}pred}$) and measured (v_{3k}) velocity of 3000m-track runs for study 1 (left; laboratory test) and study 2 (right; field test).

The individually regulated speed of CLT ranged from 9.8 to 16.8kmh^{-1} (M = 12.8kmh^{-1}; SD = 2.6kmh^{-1}). $t_{CLT\text{-}RPE20}$, the predicted time this speed could have been maintained, was M = 24.1min (SD = 10.0min) with a range of 11.8 to 50.2min.

Individual values of these variables were again used for prediction of 3000m-times by log-log-models. Mean predicted 3000m-time was 14.2min (SD = 3.0min; range: 10.0 to 18.4min) corresponding to a predicted speed of M = 13.2kmh^{-1} (SD = 2.8kmh^{-1}; range: 9.8 to 17.6kmh^{-1}). Measured 3000m-time (t_{3k}) ranged from 10.5 to 18.6min (M = 13.8min; SD = 2.8min) with a corresponding speed of 13.6kmh^{-1} (SD = 2.7kmh^{-1}; range: 9.7 to 16.9kmh^{-1}).

Correlations of predicted and measured 3000m-speed were r = .96 and ICC = .96 ($p < .001$). There was no significant difference of predicted and measured speed (M = -0.4kmh^{-1}; SD = 0.8kmh^{-1}; t_{11} = -1.60; p = .14) (Fig. 2). $v_{GXT\text{-}RPE20}$ and v_{3k} were correlated with r = .92 ($p < .001$), too, but there was a significant mean difference of 1.0kmh^{-1} (SD = 1.5kmh^{-1}; t_{11} = 2.16; p = .05) between both variables.

Discussion

The aim of the present study was to investigate, whether rating of perceived exertion, coming from submaximal GXT and CLT, allows parameter estimation of log v-log t-models in such a way, that predicting running performance would be possible with sufficient accuracy. Therefor a laboratory and a field study were conducted, in which GXT and CLT were used to predict the velocity of 3000m runs by log-log-models.

In both cases high correlations of predicted and measured speed were found, so in principle performance prediction seems possible by the presented approach. In the laboratory study ICC was only moderate and predicted speed was significant lower than measured speed. Therefor for accurate performance prediction a statistical correction seems to be necessary. But just this should be avoided, as it was the aim to predict performance directly without using further data from cross-sectional studies. Perhaps the systematic deviation of predicted and measured speed can be explained by laboratory setting and differences between treadmill- and track-running. This explanation seems insofar plausible as the supposed lack of external validity couldn´t have occurred in study 2, where GXT, CLT and 3000m competition were all conducted on the track, and where such systematic deviations indeed didn´t occur: Not only Pearson correlation was very high in study 2, the same was ICC and there was no mean difference between predicted and measured running speed. The field-test seems to be appropriate for parameter estimation of individual log-log-models, that there is no need for further statistical modification of predicted running speed. At least for 3000m-running the presented procedures can predict performance with high accuracy. For other distances validity has still to be shown. Future studies should also compare predictive validity with physiological variables like VO_2max and LT.

One advantage of the proposed method using submaximal tests is the avoidance of exhaustive load. In the present study GXT and CLT could be terminated reaching an RPE of 17 or 18. If even lower intensities are sufficient for performance prediction has still to be investigated. However, the present study has shown, that exhaustive exercise tests are not necessary for achieving high predictive accuracy. And as only RPE and running time must be measured the test is easy to apply. Hinckson and Hopkins (2005) have shown, that several exhaustive runs can be done on a single day for reliable parameter estimation of log-log-models. Future studies should examine if the here presented or similar procedures could also be used on a single day so that applicability could even be improved.

References

Billat, L.V., Koralsztein, J.P., & Morton, R.H. (1999). Time in Human Endurance Models. From Empirical Models to Physiological Models. *Sports Med ,27*(6), 359-379.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales.* Leeds: Human Kinetics.

Borg, G. (2004). Anstrengungsempfinden und körperliche Aktivität. *Dt. Ärzteblatt, 101*(15), A1016-A1021.

Faulkner, J., & Eston, R. (2008). Perceived exertion research in the 21st century: Developments, reflections and questions for the future. *J Exerc Sci Fit, 6*(1), 1-14.

Faulkner, J., Parfitt, G., & Eston, R. (2008). The rating of perceived exertion during competitive running scales with time. *Psychophysiology, 45,* 977–985.

Frederick, W.S.F. (1959). Physiological aspects of human fatigue. *Arch. Industr. Hlth., 20*, 297-302.

Grosse-Lordemann, H., & Müller, E.A. (1936). Der Einfluss der Leistung und der Arbeitsgeschwindigkeit auf das Arbeitsmaximum und den Wirkungsgrad beim Radfahren. *Arbeitsphysiologie, 9*, 454-475.

Hinckson, E.A., & Hopkins, W.G. (2005). Reliability of Time to Exhaustion Analyzed with Critical-Power and Log-Log Modelling. *Medicine & Science in Sports & Exercise, 37*(4), 696-701.

Kindermann, W. (2004). Anaerobe Schwelle. Standards der Sportmedizin. *Dtsch. Z. Sportmed., 55*(6), 161-162

Müller, E.A. (1938). Die Abhängigkeit des Arbeitsmaximums von der Leistung bei verschiedenen Personen. *Arbeitsphysiologie, 10*, 67-73.

Noakes, T.D., Snow, R.J., & Febbraio, M.A. (2004). Linear relationships between the perception of effort and the duration of constant load exercise that remains. *J. Appl. Physiol., 96*, 1571-1573.

Scharhag-Rosenberger, F., & Schommer K. (2013). Die Spiroergometrie in der Sportmedizin. *Dtsch. Z. Sportmed., 64*(12), 362-366.

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