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The relationship between individualised speed thresholds and changes in aerobic fitness in elite professional youth soccer players. A case study

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Abstract

Background: This study aimed to examine the dose-response relationship between training load and aspects of physical fitness in English Premier League (EPL) U23 soccer players. Materials and Methods: Seven male EPL U23 outfield soccer players (age 20.1±1.1 years) participated in this study and performed the Bronco test on five occasions within one season. Individualised running thresholds were employed using maximal aerobic speed (MAS), anaerobic speed reserve (ASR) and maximal sprint speed (MSS) values utilising a GPS system. Results: No significant differences in the Bronco performance between the tests ($p > 0.05$, ES = 0.101) were observed. Distance covered above 30% ASR ($r = -0.51$) and time spent above 30% ASR ($r = -0.54$) over a 2-week period displayed a moderate negative linear relationship with Bronco performance. Conclusions: ASR-based training load variables displayed the highest correlations with Bronco results. These findings support practitioners to individualise high-speed running thresholds.

Keywords

exercise, sports, training, football, performance

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Article

The relationship between individualised speed thresholds and changes in aerobic fitness in elite professional youth soccer players. A case study.

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Abstract. Background: This study aimed to examine the dose-response relationship between training load and aspects of physical fitness in English Premier League (EPL) U23 soccer players. Materials and Methods: Seven male EPL U23 outfield soccer players (age 20.1±1.1 years) participated in this study and performed the Bronco test on five occasions within one season. Individualised running thresholds were employed using maximal aerobic speed (MAS), anaerobic speed reserve (ASR) and maximal sprint speed (MSS) values utilising a GPS system. Results: No significant differences in the Bronco performance between the tests ($p > 0.05$, ES = 0.101) were observed. Distance covered above 30% ASR ($r = -0.51$) and time spent above 30% ASR ($r = -0.54$) over a 2-week period displayed a moderate negative linear relationship with Bronco performance. Conclusions: ASR-based training load variables displayed the highest correlations with Bronco results. These findings support practitioners to individualise high-speed running thresholds.

Keywords: exercise, sports, training, football, performance.

1. Introduction

In soccer, greater aerobic fitness has been associated with positive effects on the number of sprints and ball interactions and a better capacity to sustain high-intensity efforts with minimal recovery [1, 2]. Training and match load monitoring is recognised as a relevant task at any competitive level [3] with the management of high-speed running (HSR) being significant from a performance and injury risk reduction perspective [4]. Historically, generic speed thresholds have been applied to all squad athletes during training and

match-play [5]. These standardised thresholds allow for the comparison of physical performance between players and positions. However, generic speed thresholds do not account for the relative intensity and exertion imposed on the individual [6] and the variations in subsequent fatigue and recovery. Indeed, identical distances covered above generic speed thresholds may elicit contrasting internal responses in players with different physical characteristics [6]. The dose-response relationship of key metrics such as HSR is the physiological response to a given training load [7]. Some training load measures show a strong dose-response relationship with a desired outcome, such as improvements in aerobic fitness or decreased injury risk [8].

Maximal aerobic speed (MAS) and the maximal volume of oxygen consumption (VO_2 max) are measures that have previously been used to track longitudinal changes in aerobic fitness in soccer players [7]. To examine MAS, the Bronco test has been previously employed and has shown a strong correlation with other field-based MAS tests [9]. The data derived from these assessments not only facilitate the monitoring of individual athletic development but also play a pivotal role in prescribing tailored training programmes and evaluating the efficacy of training interventions. The analysis of distance covered above MAS and maximal sprinting speed (MSS) has been identified as a reliable method to provide appropriate contextual training prescription and allows the identification of an individual players' aerobic and anaerobic capacity [10, 11]. Notably, the difference between MAS and MSS has been quantified as the anaerobic speed reserve (ASR) [5, 12]. Anaerobic speed reserve has been utilised to better understand mechanical running limits and to track training progress [13]. A more individualised approach regarding the cumulative external load imposed on players together with more frequent aerobic fitness testing throughout the season may help coaches ensure training prescription is having the desired effects. Thus, the aim of the present study was to examine the dose-response relationship between various cumulative locomotive outputs and Bronco test performance in elite U23 EPL soccer players. It was hypothesised that time spent and distance covered above individualised thresholds would be a more precise predictor of aerobic fitness than time spent and distance covered above generic thresholds.

2. Materials and Methods

2.1. Training protocol

Work-load data was collected from all pitch training sessions (n = 132) and U23 competitive matches (n = 18). All training content was planned in a cyclical nature and was reflective of modern periodisation methods in elite soccer [14]. The player external physical load was undulated by design across a microcycle leading to match-play. The number of days between matches varied [15,16, and training sessions were classified based on days prior to a match (MD minus (-)) or post-match (MD plus (+)) [16]. All training sessions integrated technical, tactical, physical and mental components [14]. All physical training load data was collected at the club's official training facility with training sessions commencing at 11.00AM.

2.2. Procedures

A 10 Hz global positioning system (GPS) (Apex, STATSports, Ireland) was placed between the players' scapulae in bespoke vests and used to quantify the work-load data. The Apex units have reported good levels of accuracy and reliability in sport specific metrics (walking, jogging, running, changing direction, sprinting), in addition to non-significant and trivial differences when measuring peak velocity against gold standard measures (Stalker ATS 2.34.7 GHz, United States) [17, 18]. The present GPS system has previously reported excellent inter-unit reliability with intra-class correlation coefficients ranging from 0.94 to 0.99 [18]. The GPS signal quality and horizontal dilution of position was connected to a mean number of 20±2 satellites, range 18–23, while HDOP was 0.8. On completion of each session, GPS data were extracted using proprietary software (Apex version 4.3.8,

STATSports; Northern Ireland, UK), as software-derived data is a simpler and more efficient way for practitioners to obtain data in an applied environment, with no differences reported between processing methods (software-derived to raw processed) [19].

During the season, the Bronco test was completed on five occasions (August, December, January, March, May) to evaluate individual MAS values. Players were instructed to run from the start point to a 20-m pole and return to the start point, then to the 40-m pole and return to the start point before running to the 60-m pole and returning to the start point (Figure 1). This sequence was repeated as quickly as possible for five consecutive repetitions until the distance of 1200-m had been reached. During the test, players were informed how much time was remaining at 1-minute intervals until test completion to ensure players were performing maximally [20]. This verbal encouragement has been shown to be a motivational requirement for laboratory assessments of time to exhaustion and central fatigue [21]. Due to the changes of direction performed within the test, the following correction equation was used: 1200/(Time-20.3-s (0.7-s for each turn) = MAS ($m \cdot s^{-1}$) [9].

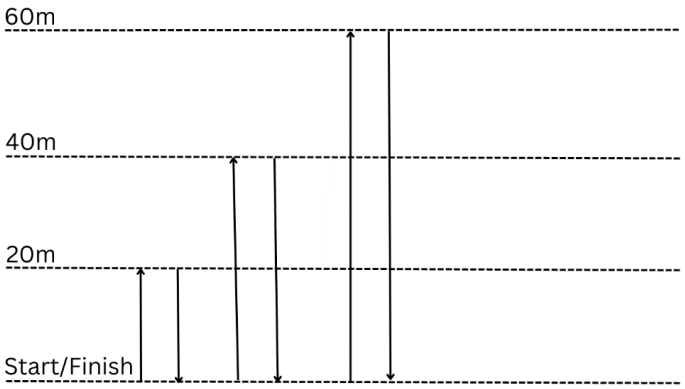


Figure 1. The 1200-m shuttle test protocol.

Throughout the season, all players performed a linear peak speed (100% of peak speed) exposure twice per week during the MD-4 training session. This exposure was completed at the end of the warm-up prior to the first football drill. Each player's MSS reached during this exposure was recorded. The researchers decided to record the highest MSS from this exposure as using average peak speed per session may be influenced by session content and positional demands and therefore would not be a true reflection of the players peak sprint capacity [22]. Speed thresholds were customised in the STATSports (APEX, 1.7) software using each individuals MAS, ASR and MSS to allow individualised analysis of the running demands [7]. All peak speeds were validated visually by a sports scientist trained in the STATSports software, to ensure no anomalies were included in the analysis. If a player produced a new MAS or MSS during the season, this was adjusted within the STATSports (APEX, 1.7) software. The additional ASR measure employed a weighted value of MAS and the MSS for each player as previously validated [5, 11]. The use of 30% ASR as opposed to ASR alone combines the functional limits of aerobic endurance and sprint capacity [11]. Training and match data were categorised into weekly blocks from Monday to Sunday. Data collected for analysis from the GPS included: HSR distance (distance covered above 5.5 m/s measured in metres), distance covered at speed above each player's MAS measured in metres, time spent at speed above

each player's MAS measured in minutes, distance above each player's 30% ASR measured in metres, and time spent above each player's 30% ASR measured in minutes.

2.3. Participants

Seventeen male U23 EPL outfield soccer players with aged 19.6±1.2 years, with a height of 1.8±0.05 m, and body mass of 75.2±5.6 kg (mean ± standard deviation (SD)), at the start of the 2022–2023 season were recruited for the present study. However, due to injury and availability, only seven players (age 20.1±1.1 years, height 1.78±0.07 m, body mass 73.9±5.7 kg) participated. Players were classified and matched by position and grouped as follows: wide defender (WD) $n = 1$, centre midfield (CM) $n = 2$, wide forward (WF) $n = 1$, and centre forward (CF) $n = 3$. Goal-keepers were excluded from the investigation due to the position-specific nature of match activities and low running demands [23]. Approval for the study was provided by the club from which the data was obtained [24], and all participants provided written informed consent. The study was performed in accordance with the Helsinki Declaration (2013) principles, and ethical approval was granted by the local Ethics Committee of the University of Central Lancashire (BAHSS 646 dated 17/04/2019). To ensure participant confidentiality, all data were anonymised before analysis. Participants were fully familiarised with the experimental procedures within this study due to regular protocols implemented as part of the clubs' performance monitoring strategy.

2.4. Statistical Analyses

To test for statistical differences in mean Bronco performance over time, a repeated measure analysis of variances (RMANOVA) test was conducted (Table 1). Prior to analysis, tests of normality were conducted using the Shapiro-Wilk test [25]. All data was visually assessed for normality using QQ Plots. If the assumption of sphericity was violated, Greenhouse-Geisser corrections were conducted. The alpha was set at 0.05. Results are reported alongside ω^2 effect sizes (ES) to control for the small sample size. The ω^2 effect sizes (ES) are interpreted as: < 0.01 "trivial", < 0.1 "small", < 0.06 "medium", > 0.14 "large". Post-hoc analysis was conducted with Bonferroni corrections to control for Type I errors and reported alongside Cohen's d effect sizes [26]. Cohen's d effect sizes were interpreted as follows: $d < 0.2$ "small", $d < 0.5$ "medium", $d > 0.8$ "large" [26]. The relationship between training load dose variables and Bronco performances were analysed using Spearman rank correlations and presented as a correlation matrix. Analysis was conducted in the JASP statistical software (Version 0.18.0) and the Python 3.7 programming language.

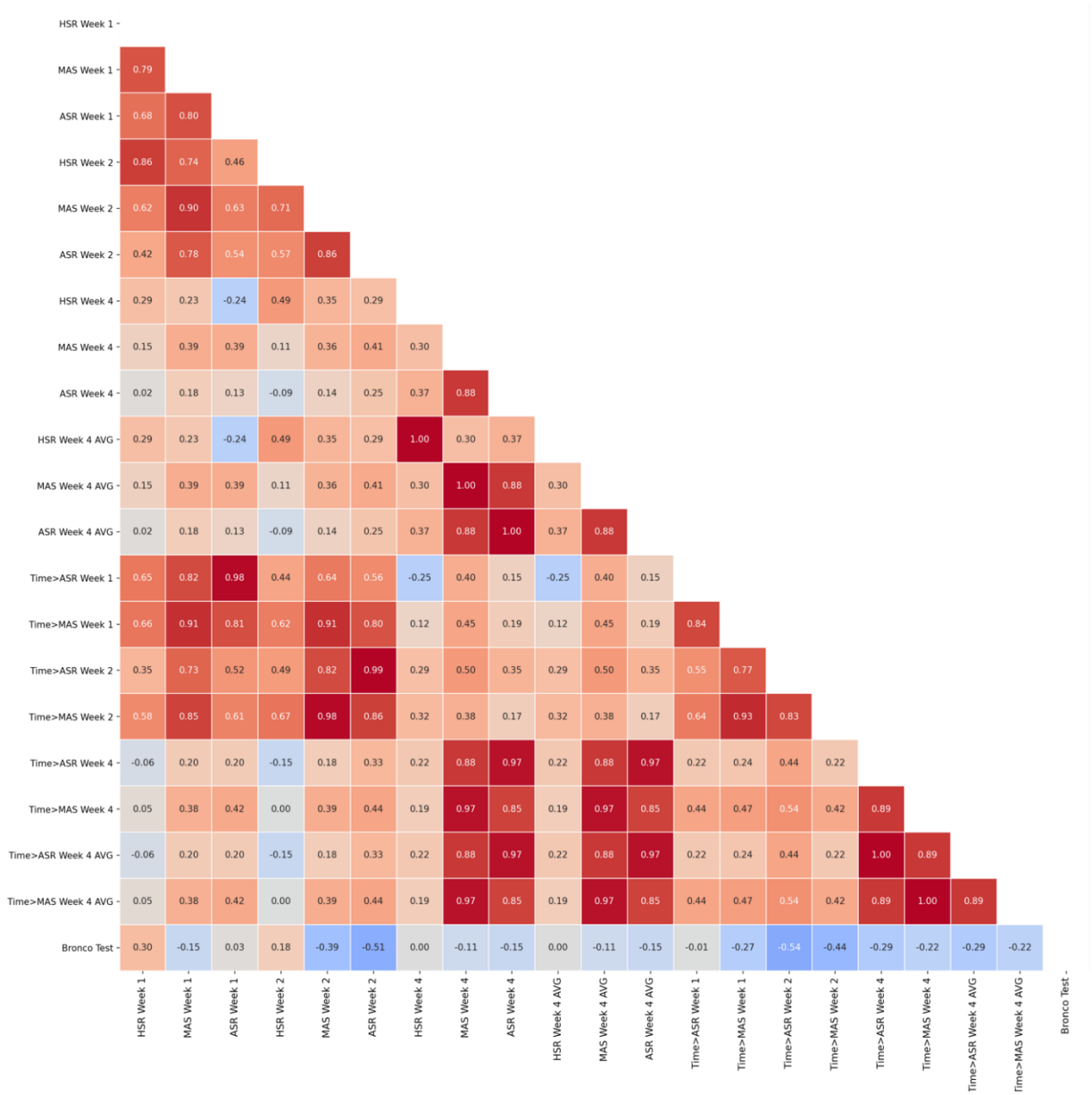
3. Results

The mean (± SD) MAS, MSS and related ASR value were 4.73±0.24 $m \cdot s^{-1}$, 9.81±0.31 $m \cdot s^{-1}$ and 5.09±0.19 $m \cdot s^{-1}$, respectively. The results indicate that there are no significant differences in the mean Bronco performances between tests ($p > 0.05$, ES = 0.10). Training load dose variables related to ASR demonstrated the strongest correlation with Bronco results. The time spent above 30% ASR over a 2-week period shows the strongest negative linear relationship across all examined metrics (r = -0.54), with distance covered above 30% ASR over a 2-week period showing the next strongest negative linear relationship (r = -0.51).

Table 1. Repeated Measures ANOVA results for Bronco performance across time points.

Cases	Sum of Squares	df	Mean Square	F	p
Bronco Test	0.126	1.076	0.117	2.795	0.166

Figure 2. Correlation matrix of training load variables and Bronco results.



HSR_1week = Total distance covered above 5.5m/s in a one week period, MAS_1week = Total distance covered above each players MAS in a one week period, ASR_1week = Total distance covered above each players 30% ASR in a one week period, HSR_2week = Total distance covered above 5.5m/s in a two week period, MAS_2week = Total distance covered above each players MAS in a two week period, ASR_2week = Total distance covered above each players 30% ASR in a two week period, HSR_4week = Total distance covered above 5.5m/s in a two week period, MAS_4week = Total distance covered above each players MAS in a four week period, ASR_4week = Total distance covered above each players 30% ASR in a four week period, HSR_4week_Ave = Average weekly distance covered above 5.5m/s over a four week period, MAS_4week_Ave = Average weekly distance covered above each players MAS over four week period, ASR_4week_Ave = Average weekly distance covered above each players 30% ASR over a four week period, Time>ASR_1WK = Total time spent above each players 30% ASR in a one week period, Time>MAS_1WK = Total time spent above each players MAS in a one week period, Time>ASR_2WK = Total time spent above each players 30% ASR in a two week period, Time>MAS_2WK = Total time spent above each players MAS in

a two week period, Time>ASR_4WK = Total time spent above each players 30% ASR in a two week period, Time>MAS_4WK = Total time spent above each players MAS in a two week period, Time>ASR_4WK_Ave = Average time spent above each players 30% ASR over a 4 week period, Time>MAS_4WK_Ave = Average time spent above each players MAS over a week period

4. Discussion

The aim of this study was to examine the dose-response relationship between various running outputs and aspects of physical fitness in elite U23 EPL soccer players during the 2022–2023 season. A key finding of this research is the lack of a significant difference in mean Bronco performance over the course of the season. Furthermore, no significant dose-response relationship was observed between generic HSR thresholds and Bronco test performance. Time spent above 30% ASR over a 2-week period showed the strongest negative linear relationship across all examined metrics (r = -0.54), with distance covered above 30% ASR over a 2-week period showing the next strongest negative linear relationship (r = -0.51) (Figure 2).

In contrast to Fitzpatrick et al. [7], the current study findings did not find a significant dose-response relationship between any of the metrics examined and the Bronco test performance. In comparison, the experimental approach of Fitzpatrick et al. [7] occurred during the pre-season period, which may partly explain the improvements in the observed aerobic performance. Research has shown improvements in aerobic performance in pre-season followed by a plateau or decrease during the in-season period [27, 28]. One aim of the current study was to support practitioners in the athlete load monitoring process by outlining a systematic procedure of data reduction to allow the most relevant injury-risk and aerobic performance measures to be identified and monitored. Time spent above 30% ASR over a 2-week period showed the strongest negative linear relationship from all examined metrics (r = -0.54), and distance covered above 30% ASR over a 2-week period showing the next strongest negative linear relationship (r = -0.51). This may partly be explained by the demands of soccer that require elite level players to have well-developed aerobic and anaerobic energy systems [29]. Collison et al. [30] reported that exercise prescription using ASR reduces the variability in supra-maximal interval running performance in comparison to prescription by MAS in Australian Rules Football players. This reduction in variability ensures all athletes are exposed to similar physiological demands and, in turn, similar physiological adaptations [30]. Therefore, prescribing and measuring intensities based around anabolic metabolism may be an effective method of conditioning soccer players. Therefore, these findings illustrate the potential advantages of utilising individualised HSR thresholds instead of the typically applied generic thresholds.

Despite the previous strengths of this study, some limitations should be listed: a) the study was conducted using a small sample size from one team. This may limit the generalisation of the results and should only be considered in a similar cohort; b) the regular testing of professional soccer players has proven to be rather complex as the present sample size illustrates, and c) fixture congestion, injuries and player availability had an impact on the number of tests each player was able to perform across the study season.

5. Conclusions

This research illustrated that individualised speed thresholds had a stronger relationship with the Bronco test performance than generic thresholds. This has significance for practitioners in terms of training prescription and design. It supports practitioners to individualise speed thresholds from pre-season test data with the knowledge that such thresholds may not significantly alter over the course of the season. That said, future research should aim to explore the dose-response relationship between aerobic and anaerobic performance and ASR derived metrics in addition to ASR prescribed high-intensity interval training interventions. No significant differences in mean Bronco performance over the course of the season were noted. The Bronco test has the potential, with a larger

sample size, to provide an advantage of employing individualised speed thresholds instead of generic thresholds. Indeed, all generic threshold metrics only indicated a negligible correlation.

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