Establishing between-session reliability and a threshold for practically meaningful change in aerobic performance during a submaximal fitness test in professional soccer players.

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Submaximal Fitness Test (SMFT) | Heart Rate (HRex) | Reliability | Aerobic Performance | Professional Soccer Players | Training Adaptations | Minimal Detectable Change (MDC) | Internal Load | Physiological Monitoring | Performance Assessment

Headline

Several validated and reliable assessments of maximal aerobic performance currently exist to bench-mark elite soccer players (1-4). While these should be considered gold standard, due to their fatigue-inducing nature, their utilisation may not always be appropriate (5). As such, the emergence of submaximal fitness tests (SMFT) are of appeal to practitioners as a fast, time-effective and non-intrusive means to assess changes in players physiology (6-7).

Aim

The aim of this study was to determine the between-session reliability of a continuous-fixed SMFT (6) in professional soccer players. The secondary aim was to examine the protocols sensitivity to change over an intense training camp and tentatively propose a threshold for practically meaningful change in performance.

Methods

Fourteen senior professional players (age: 25 ± 4.1 years; height: 182.3 ± 5.1 cm; body mass: 80.1 ± 5.2 kg; 5 Defenders, 5 Midfielders, 4 Attackers) from a Scottish Premiership club agreed to take part in the present study. Data were collected in line with clubs daily practices which all conformed with the declaration of Helsinki.

Procedures

All trials were performed during a training camp during the winter break of the competitive season (Dubai, UAE; January). To assess between-session reliability, a SMFT was delivered on Day 1 and Day 2 of the training camp. To control for the confounding influence of fatigue-related symptoms, only low volume/low intensity training was delivered between trials. Thereafter, following a period of arduous training, a further trial was delivered on Day 6 of the training camp to assess changes in performance. From this, any training-derived improvements in performance were proposed as an economically-valid threshold for practically meaningful change. The experimental timeline is shown in Figure 1. All trials were held in the morning prior to any other form of training (Circa 10am). Quantification of the training stimulus, which aimed to induce a training effect across the training camp is provided in Figure 2. Internal load (time (minutes) above 85% of players maximal heart rate (HRmax)) and external training load (total distance (metres), high intensity running (distance (metres) covered above 19.8 kph) and accelerations (count above 3 m/s^2)) data was measured using Polar H10 heart rate monitors and Catapult S7 GPS units, respectively.

SMFT

Following the recommendations of Shushan et al. (6), a continuous-fixed SMFT was selected (3 minutes of 50 metre (m) shuttles at 11 kilometres per hour (kph)) with exercise heart rate (HRex) (average HRmax % during the last 30 seconds of the trial) chosen as the primary outcome measure. To standardise starting HR at the trial onset, players were instructed to stand at the start-line for 2 minutes prior to beginning the SMFT. During the trial, pacing was assisted via a metronome every 25m. All trials were performed on grass (surface: firm/dry; conditions: still, circa 19°C).

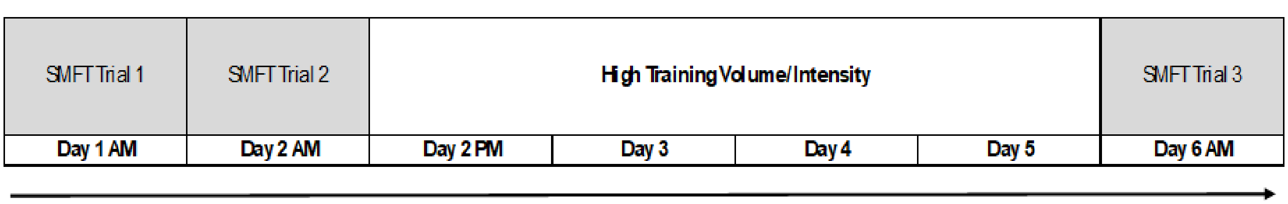

Fig. 1. Experimental timeline.

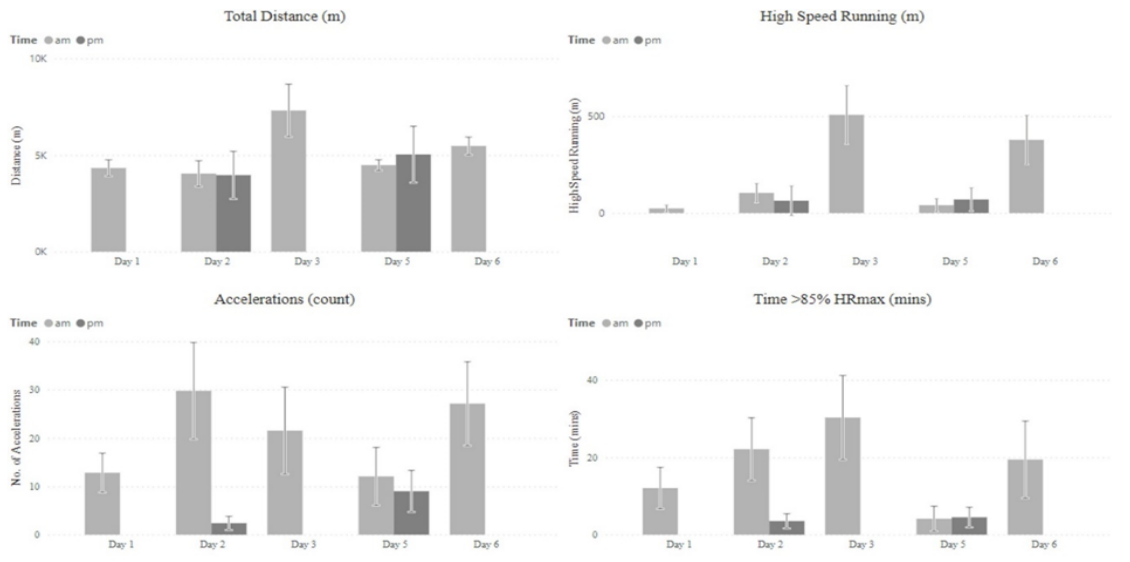

Fig. 2. Quantification of the training stimulus during the training camp.

Statistical Analysis

Descriptive statistics are reported as group mean score ± standard deviations (SD). Between-session reliability (Day 1 and Day 2) was calculated and expressed as typical error (TE), coefficient of variation (CV%) and interclass correlation (ICC) using a custom spreadsheet (8). To offer practitioners a value for meaningful change in HRex, that exceeds the measurement error associated with this protocol, a minimum detectable change (MDC) at a confidence level of 90% was calculated using the following equation; MDC = TE x 1.65 x $\sqrt{2}$ (9). To establish a notionally acceptable threshold for practically meaningful change, HRex were compared between Day 1 and Day 6 via absolute and standardised differences in the mean (effect size: Cohen's d) with 90% confidence intervals applied. Data were analysed using Jamovi (The jamovi Project. n. d. *jamovi* 2.3.21).

Results

Group mean values for the SMFT (between-session reliability, n = 14) were 80% on both Day 1 and Day 2. The statistical analysis is shown in Table 1. Group mean values for the SMFT on Day 1 and Day 6 (n = 11), were 78% and 76%, respectively. The statistical analyses is shown in Figure 3 and Table 2.

Table 1. Between-session reliability statistics for the continuous-fixed submaximal fitness test (SMFT). Typical error (TE), interclass correlation coefficient (ICC), coefficient of variation (CV%) and minimum detectable change (MDC) with 90% confidence level.

	Trial 1-2	
SMFT	TE (90% CI)	1.2% (0.96, 1.86)
	ICC (90% CI)	0.92 (0.81, 0.97)
	CV% (90% CI)	1.0 (0.45, 1.55)
	MDC	2.9%

Discussion

The main finding of this study was that a continuous-fixed SMFT demonstrated good between-session reliability and therefore may offer practitioners a robust method to track changes in aerobic performance capability. Attractive features of the SMFT include the ease of delivery (minimally-intrusive/non-fatiguing), player/coach buy-in and the opportunity for it to be adopted earlier in the rehabilitation process before maximal testing is appropriate. From this data, the change threshold required to exceed the measurement error associated with this protocol (MDC) is 3% (6 bpm). Interestingly, these findings are in line with previous research in professional football where HRex was measured during a continuous-fixed protocol (12 kph, 4-min) (10). Specifically, the authors reported CV%, ICC and an MDC of 1.4%, 0.95 and 5 bpm, respectively.

The observed change in HRex over the training camp (Day 1 to Day 6) was also 3%. As this value is equal to the aforementioned measurement error, it implies that HRex was sensitive to training adaptations over this short-duration, but intense, training camp. Tentatively, the observed change may provide a useful index for practically-meaningful change for practitioners to consider while examining their own data. Previously, changes in HRex during a 5-minute submaximal protocol have been observed over a training camp of longer duration (2-weeks) (5). In this case, a reduction of around 8% was observed (92% to 84% of HRmax over the duration of the training camp) whereas in the current study the corresponding change in HRex was 3%.

While the present data indicates positive training adaptations occurred between Day 1 and Day 6, physiologically, this outcome is likely to be associated with increased plasma volume, driven by warmer temperatures, leading to greater stroke volume and cardiac output rather than changes in fitness per se (5, 11). Indeed, previously a period of 1-week has been recommended (12-13) to confidently interpret fitness trends from HR measures and account for short-term fluctuations in sympathetic activity driven by acute training fatigue (5, 14).

As an alternative means of gauging substantial change, a smallest worthwhile change (SWC) value of 1% for HRex during submaximal protocols has been outlined (15-16). When combined with the TE, changes in physiological measures at an individual level may be assessed (17). Specifically, SWC + TE has been proposed as an indication of substantial change (17), which from the present reliability data would suggest a substantial change threshold of 2-3% (TE = 1-2% with 90% CI).

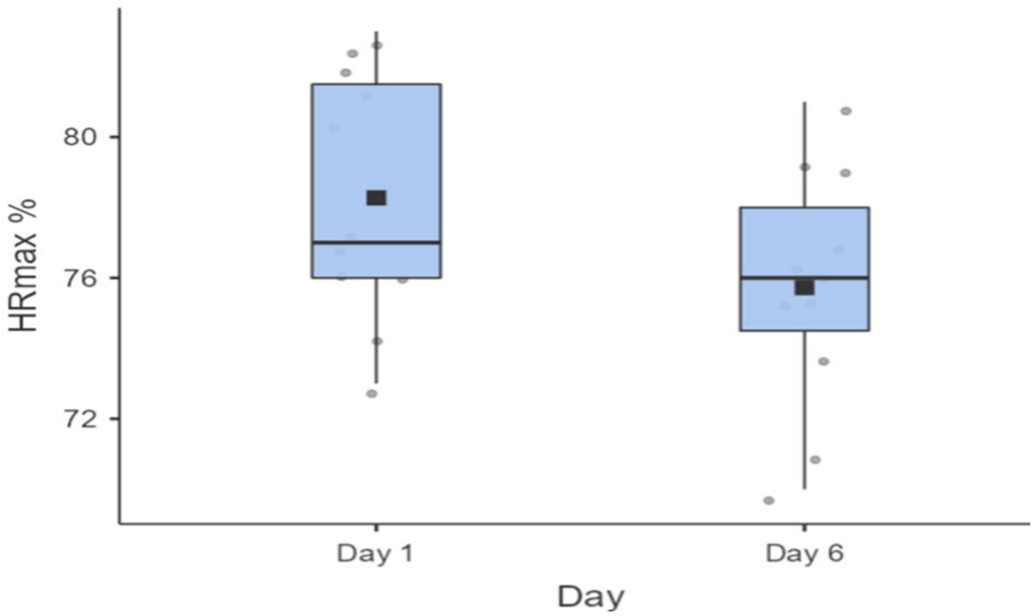

Fig. 3. **Box plots showing jittered data points for HRex for trials on Day 1 and Day 6.**

Table 2. **Differences in group mean exercise heart rate (average during the final 30 seconds of the SMFT) (HRex). Standardised effect size (Cohen's d) with qualitative inference and raw effect.**

SMFT Outcome measure	Effect Size (90% CI)	Qualitative inference (Distribution-based)	Raw Effect
HRex	0.8 (0.2, 1.37)	Moderate	3%

Practical applications

- This reliability study indicates a change in HRex performance of 3% during a continuous-fixed submaximal fitness test provides a threshold for detectable change (MDC with 90% confidence).
- From a practical perspective, the current analysis observed a positive training effect (Day 1 to Day 6) equating to change of 3% following an intense short-duration training stimulus.
- As the MDC is equal to the practically relevant change outlined above (both 3%), the SMFT has the capability to capture meaningful change in aerobic performance in elite soccer players.
- As such, practitioners should have confidence this protocol is sensitive to positive chronic training effects such as those targeted over pre-season or during long-term rehabilitation. When using the protocol described in this study, changes in HRex of 3% or greater should be considered a meaningful change in performance in professional football players.

Limitations

- A limitation of the present study is the small sample size, although this is common in studies of players at professional level.
- Given this data was gathered in a real-world setting with high ecological validity, it was not possible to fully control for the confounding influence of fatigue-related symptoms during the final trial on Day 6.
- However, it should be noted, training in the 48-hours prior to the final trial were recovery and tactically themed with minimal repetitive high intensity actions.
- Heat-related potentiation of exercise-induced blood plasma expansion may have contributed to improved HRex, particularly given the contrast with UK winter temperatures from which players were acutely acclimatised to prior to the training camp. However, temperature conditions were not considered extreme (in line with UK summer time) and were consistent across the 3 trials (circa 19° Celsius).
- Should practitioners prefer to utilise alternative thresholds for determining substantial, practically relevant change; the described SWC + TE may serve as a useful methodology.

- In such case, from the present data the MDC (3%) slightly exceeds the TE + SWC (2-3%) illuminating the potential for very small, but potentially important changes in performance being beyond the measuring capability of this protocol.

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