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Title: Are aerobic fitness and repeated sprint ability linked to fatigue in professional soccer match-play? A pilot study.

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Running Head: Fitness and match fatigue in soccer

Abstract

This investigation examined the association between aerobic fitness and repeated sprint ability and match-related fatigue in 9 professional outfield soccer players. Aerobic fitness using maximal aerobic speed (MAS) was determined via a continuous progressive incremental running test conducted on a motorised treadmill. A repeated sprint ability test (6 successive 6 s sprints separated by 20 s passive recovery) was performed on a non-motorised treadmill to determine mean and best sprint times and a percentage decrement score (%PD). A total of 114 observations of physical performance derived using computerised time motion analyses were collected from 33 matches. Correlations between fitness test and match-play measures were examined for 1) accumulated fatigue: percentage difference between halves for total distance covered per minute, distance run at high-intensities (HIR, actions for 1s duration, >19.1 km/h) per minute, mean recovery time between high-intensity runs, and percentage difference between the distance covered in HIR in the first 5- and 15-minute periods versus the final 5- and 15-minute periods respectively in normal time; and for 2) transient fatigue: percentage difference between the distance covered in HIR in a peak 5-minute period and the subsequent 5-minute period and for the latter compared to the mean for all other 5-minute periods. No significant relationships were observed between MAS and fatigue scores (magnitude of associations: trivial to large). For mean and best sprint times and %PD, the only reported significant correlation ($r=0.77$, magnitude of association: very large, $p<0.05$) was between %PD and the % difference across halves for mean recovery time between high-intensity runs (magnitude of other associations: small to large). Criterion measures from tests of aerobic fitness and repeated sprint ability might not

accurately depict a player’s capacity to resist fatigue during professional soccer competition.

Key words: time motion analysis, physical performance, locomotor activity,

Introduction

In professional soccer, a strong relationship has been observed between measures of physical fitness derived from tests of repeated sprint ability [1,2], intermittent endurance [3] and aerobic capacity [2] and running performance in competition determined from time motion analyses data. Unfortunately, these studies have generally only examined associations with ‘overall’ time motion measures of running performance such as the total distance run or that covered in sprinting. The potential relationship between fitness scores and declines in competitive physical performance in professional soccer players has up to now not received any attention despite the comprehensive body of research from time motion analyses that has indirectly demonstrated the existence of fatigue during match-play [4]. To our knowledge, only two studies, both conducted in elite youth soccer players, have addressed this gap in the literature [5,6]. In the former for example [5], despite a significant association between intermittent-endurance fitness (Yo-Yo IR1 test) and overall distance covered in high-intensity activity, no relationship was observed between fitness measures and first- vs. second-half decrements in running distance.

Nevertheless, the occurrence of accumulated fatigue represented by a significant drop in running distance between halves and towards the latter stages of games and transient fatigue represented by impaired running performance immediately after short-term periods of intense activity is common in professional soccer match-play [7]. In addition, field tests of sprinting ability have demonstrated declines in performance directly after completion of a match [8] and after intense periods of running activity in the first and second halves [9]. In theory therefore, a higher level of anaerobic and/or aerobic fitness might enable ‘protection’ against these forms of game-induced fatigue and potentially reduce the occurrence of declines in running performance. Consequently, the aim of this pilot study was to examine whether an association exists between measures of physical fitness and match-induced fatigue determined via time motion analyses in professional soccer players.

Methods & Subjects

Subjects

A total of 9 first-team outfield professional soccer players participated (age: 26.1±3.0 years; height: 180.1±8.2 cm; weight 78.1±8.1 kg). The small sample size was in part due to the inclusion of players in whom measures of both aerobic fitness and repeated sprint ability were available. While player consent was obtained and approval for the study obtained from their club, these data arose as a condition of employment in which player performance was routinely measured over the course of the competitive season [10]. Therefore, usual appropriate ethics committee clearance was not required.

Fitness testing

All participants were free from illness and injury at the time of fitness testing. All test protocols were performed at the same time of day and the players were familiar with the test procedures.

Aerobic fitness was indirectly determined via a continuous progressive incremental running test performed on a motorised treadmill (Desmo 3.0, Woodway, Waukesha, WI, USA) at the beginning of the competitive season. This protocol employed a 4-minute warm-up run performed at 10 km/h on a constant 1.5% gradient followed by 2 km/h increments for 4-minute stages until voluntary exhaustion [11]. The running speed attained at exhaustion (maximal aerobic speed) was used as the criterion measure of aerobic fitness [2].

A repeated sprint ability test (RSA) was performed on a non-motorised treadmill (Force 3.0, Woodway, Waukesha, WI, USA). This test was done during the mid-season winter break as logistical reasons prevented assessment during the same period as the aerobic fitness assessment. Following a 15-minute standardized warm-up, the protocol entailed 6 consecutive 6 s sprints separated by 20 s passive recovery periods. Criterion measures of repeated sprint ability included mean and best sprint time and a percentage decrement score (%PD) across the 6 sprints [1].

Measures of match performance

Physical performance via time motion analysis was analysed in 33 matches played over the course of the 2010/2011 competitive season (League, domestic Cup and UEFA Europa League games). A total of 114 individual match observations (completion of entire game) were generated. The recognised difficulties in obtaining systematic information on match running performance (due to player absence through injury and/or non-selection, unavailability of the match analysis system in away games etc.) [12] led to collection of a minimum of 5 and a maximum of 28 individual performance observations for the 9 players with these randomly obtained at different time points across the competitive season.

Time motion analyses data were obtained using a semi-automatic computerised motion analysis tracking system (AMISCO, Sport Universal Process, Nice, France).

The workings, accuracy and reliability of this system in measuring player movements in elite soccer competition have been described elsewhere [4].

The association between MAS and RSA (mean, best and %PD) and the following match-play measures [7] was examined: a) accumulated fatigue: percentage difference between halves for: total distance, distance run at high-intensities (HIR; running performed at speeds >19.8 km/h for a minimum duration of 1 s) per minute and mean recovery time between high-intensity runs; and percentage difference between the distance covered in HIR in the first 5- and 15-minute periods versus the final 5- and 15-minute periods respectively in normal time; b) transient fatigue: percentage difference between the distance covered in HIR in a peak 5-minute period and the subsequent 5-minute period and for the latter compared to the mean for all other 5-minute periods (minus peak period).

Statistical analyses

Statistical analyses were conducted using SPSS for Windows Version 13.0 (SPSS Inc., Chicago, IL, USA). Changes in running performance in all players across selected time periods are expressed as a percentage difference (mean ± SD). The normality of the data was verified using the Shapiro-Wilk test. Pearson's product-moment correlations were employed to examine relationships between fitness measures and percentage changes in match data. The level of statistical significance was set at $p<0.05$. The correlation coefficients (r) (presented with 95% Confidence Intervals [95% CI]) were assessed according to the following scale of magnitude: ≤0.1, trivial; >0.1-0.3, small; >0.3-0.5, moderate; >0.5-0.7, large; >0.7-0.9, very large; and >0.9-1.0, almost perfect [13].

Results:

The mean scores across all players for MAS and mean, best and %PD respectively were 17.7±0.9 km/h and 4.34±0.32 s, 3.91±0.34 s and -9.3±3.1%. While performance dropped in all match-play measures of accumulated and transient fatigue across the selected match periods, no significant relationships (magnitude range for the associations: trivial to large) were observed between MAS and any of the fatigue scores (Table 1). Regarding mean, best & %PD scores, the only significant correlation observed was with the % difference across halves for mean recovery time between high-intensity runs ($r=0.77$, very large, $p<0.05$). The magnitude of the other associations ranged from small to large.

Insert Table I about here.

Discussion

To our knowledge, this study was the first to investigate the association between fitness and match-induced fatigue determined via time motion analyses in professional soccer players. Here, correlation analyses showed that maximal aerobic speed and repeated sprint ability were generally unrelated and even inversely associated (albeit non-significantly) to accumulated and transient match fatigue.

The fitness components examined here have previously been associated with overall measures of running performance (total distance run and that covered at high-intensities) in professional soccer players [2]. However, despite the moderate to large magnitude of several of the present correlations, inconsistencies across values and the general lack of significant relationships tend to raise doubts on the capacity and pertinence of the present tests as valid indicators for predicting a player's ability to resist fatigue in match-play. Indeed, the increase in mean recovery time between consecutive high-intensity actions was significantly and positively correlated to the negative percentage decrement observed across sprints in the RSA test inferring that lower decrement scores were actually associated with greater second-half mean recovery times. Thus it would seem that despite the observed declines in distances covered across match periods, higher levels of aerobic fitness and repeated sprint ability as measured by the current tests were not necessarily associated with a better capacity to resist fatigue in match-play. The present results, while admittedly using different fitness test protocols, partly concord with those observed in young elite soccer players in whom no relationships were found between field tests of intermittent-endurance (Yo-Yo IR1) [5] and aerobic fitness (maximal incremental running test) [6] and first- vs. second-half decrements in match running activities.

One explanation for these results could be that the logical validity or intrinsic characteristics of the present fitness tests are simply unrelated to actual match-play demands. Additional work is thus warranted to examine associations with intermittent-type test performance (e.g., Yo-Yo tests) [3] and submaximal parameters of aerobic fitness (e.g., ventilatory or lactate threshold) [14]. An alternative explanation could be that match-related fatigue is simply a function of the physical demands associated with playing positions and/or its link to tactical choices made by coaching staff [6]. While relating playing position to match-related fatigue and player fitness scores would have been pertinent, the small sample size used did not permit this sub-analysis. However, doubts have recently been raised on the use, in isolation, of time-motion analyses to identify occurrence of player fatigue in match-play represented by changes in distance covered across selected time intervals [15]. Declines in running performance identified here might have been over- or under-estimated due to confounding factors such as the time the ball was in play, ball possession and score line [4]. Finally, the players might simply have adopted a pacing strategy whereby they modulated, by intermittently lowering, their physical efforts in an attempt to avoid fatigue [16].

A major limitation of this study is the small sample of players (n=9) from a single team which might have left it statistically underpowered. Indeed, the wide confidence intervals for the correlations tend to prevent formulation of any firm conclusions as these frequently overlapped small positive and negative values thus the magnitude of the correlations can be considered unclear [6, 13]. Here, only players who completed both test protocols were included for analysis which substantially reduced the sample size and larger and wider scale samples of professional teams and players are thus necessary to verify the present findings. Ideally, physical performance data in the same players clustered from matches played over a shorter period closer to the tests would also have helped to account for and potentially reduce the effect of any changes across the season in aerobic fitness and repeated sprint ability as well as the inherent high variability (expressed as % coefficient of variation) in competitive physical performance [17]. However, as explained earlier, in the present setting and as commonly experienced in other professional soccer club environments this was practically unfeasible due to non-availability (e.g., illness/injury) and/or non-selection of players and the lack of time motion analyses data for every game played (notably in away matches) across the season [12].

Conclusion

Within the restrictions of the present sample size and study design, these results imply that practitioners should be aware that criterion measures from fitness tests such as aerobic fitness and repeated sprint ability might not accurately depict a player's capacity to resist fatigue during professional soccer competition. Similar investigations using larger sample sizes and additional measures of physical fitness as well as accounting for the present study limitations are nevertheless warranted.

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Table I: Associations between measures of aerobic fitness and repeated sprint ability and match-related fatigue in 9 professional soccer players.

				Correlation coefficient (95%CI)			
Match period			% Difference	RSA Best	RSA Mean	RSA % Decrement Score	Maximal Aerobic Speed
1st vs. 2nd Half							
Total distance (m/min)[#]	124.4±8.2	117.2±6.8	-5.8±1.9	0.51 (-0.23 to 0.88)	0.39 (-0.38 to 0.84)	-0.43 (-0.85 to 0.34)	-0.24 (-0.78 to 0.50)
High-intensity running (m/min)	9.6±2.2	9.4±1.9	-2.5±8.5	0.45 (-0.31 to 0.86)	0.44 (-0.85 to 0.34)	-0.41 (-0.84 to 0.36)	-0.35 (-0.82 to 0.41)
High-intensity action recovery time (s)	100.0±25.9	117.1±26.2	+17.1±8.7	-0.44 (-0.85 to 0.34)	-0.39 (-0.84 to 0.37)	*+0.77 (0.22 to 0.95)	0.20 (-0.54 to 0.76)
Total distance covered in selected match periods (m)							
0-15min vs. 75-90mins	153.7±41.3	152.9±30.7	-0.5±13.4	0.56 (-0.16 to 0.89)	0.45 (-0.30 to 0.86)	-0.38 (-0.84 to 0.38)	-0.55 (-0.89 to 0.18)
0-5mins vs. 85-90mins	58.5±15.6	56.3±12.3	-3.9±30.2	0.34 (-0.42 to 0.82)	0.17 (-0.55 to 0.75)	-0.43 (-0.85 to 0.33)	0.03 (-0.65 to 0.68)
Peak 5mins vs Following 5mins	108.5±14.4	39.7±14.7	-63.4±8.4	-0.37 (-0.83 to 0.39)	-0.52 (-0.88 to 0.22)	-0.14 (-0.75 to 0.58)	0.28 (-0.46 to 0.80)
Peak 5mins vs Mean for all 5mins	45.1±10.0	38.3±14.7	-15.2±15.8	-0.51 (-0.88 to 0.24)	-0.62 (-0.91 to 0.08)	-0.16 (-0.75 to 0.56)	0.39 (-0.37 to 0.83)

*Significant association ($p<0.05$) between the % Decrement Score across sprints for the test of repeated sprint ability (RSA) and the difference in mean recovery time between high-intensity actions across match halves.

[#]m/min: metres covered per minute