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Physiological and perceptual responses of youth soccer players to an intensified period of competition.

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Title: Physiological and perceptual responses of youth soccer players to an intensified period of competition.

Running head: Intensified Competitive Period in Youth Soccer Players

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ABSTRACT

Intensified periods of competition create large increase in physical workload and can expose soccer players to numerous playing styles. The purpose of the study was to investigate the response of youth soccer players to an intensified period of competition and assess whether initial fitness influenced outcomes. Elite males across two consecutive years (n_1=18, n_2=18) were assessed for lower body strength and high-intensity endurance. Objective and subjective measures of fatigue were collected throughout five-day international tournaments using countermovement jumps (CMJ), a perceptual wellness questionnaire and match GPS data. Mixed effects models quantified the effects of time and fitness on outcomes. In general, results were consistent across both years. No significant interaction effects were obtained between time and fitness variables for any outcome ($\chi_4^2 \leq 6.5$; $p \geq .225$). CMJ height and power remained consistent across both tournaments ($\chi_4^2 \leq 5.3$; $p \geq .262$). In contrast, significant ($\chi_4^2 \geq 17.7$; $p < .003$) effects of time were obtained for GPS data with metrics exhibiting U-shape patterns with values returning to initial levels during final games. Greater variation was obtained for perceptual wellness data, however, responses to general muscle soreness and stress levels showed consistent decreases across both years ($\chi_4^2 \geq 12.7$; $p \leq .013$). Practitioners should be aware that basic measures collected from CMJ and GPS data may not be sensitive to fatigue accrued in youth soccer players across intensified periods of competition. In contrast, simple perceptual measures including general muscle soreness and stress may be more sensitive and assist with implementation of active recovery or load management strategies.

Keywords: Fatigue; Monitoring; GPS; Wellness

INTRODUCTION

In youth soccer, intensified periods of competition are frequently used to expose players to different playing styles within short-time periods. In youth academy settings these intensified periods of competitions may take the form of soccer tournaments involving up to two matches per day and five to six matches within a three- to five-day period [1]. Previous research conducted with youth soccer players has shown that performance can be negatively influenced when consecutive matches are performed with limited recovery time [1, 2]. Given the large increase in physical workload created during condensed soccer tournaments it may be expected that perceptual and neuromuscular fatigue, as commonly assessed by changes in questionnaire based measurements and reductions in simple measures of muscle function or in-game actions [3] will be accrued, and performance negatively affected, particularly towards latter stages of the competition. Previous research in rugby league players and youth footballers respectively, has shown negative effects on perceived wellness [4] and in-game running actions[1]. These findings suggest a negative effect on both the perceptual and physical fatigue response. However, recent research conducted by Gibson et al.[5] with youth soccer players at international competition reported no difference in daily measures of lower body power or perceived wellness across low or high match exposure. These contrasting findings indicate further investigation regarding the effects of intensified periods of competition is warranted.

The effects of intensified periods of competition are more clearly established for adult soccer players. Previous studies have reported elevated markers associated with muscle damage [6] and reduced anaerobic performance up to 72 hours post-matches [7-9]. However, research indicates that outcomes related to external work capacity, including distance covered during games at various speeds, may be unaffected by intensified periods of competition in elite adult soccer players [10-13]. Comparatively few studies have assessed similar conditions with youth populations in soccer. Two recent studies conducted with elite youth soccer players by Arruda et al. [1] and Moreira et al. [14] investigated the response of various physiological and external work capacity measures across a tournament [1, 14]. Arruda et al. [1] reported a trend of decreased frequency of accelerations (>1.8 m/s^2) per minute across the three-day, five-match tournament. In contrast, other external work measures including total distance covered, total distance covered per minute, high-intensity running distance and frequency of high-intensity running efforts were unaffected over the period [1]. Similar mixed findings were reported by Moreira et al. [14] with physiological and perceptual measures over seven matches played in seven-days. The authors reported significant decreases in daily salivary concentrations of testosterone and mucosal immunity (SIgA). However, the results demonstrated no change in salivary cortisol concentrations or ratings of perceived exertion (RPE) across the intensified period [14]. Collectively, the findings from these studies suggest that only a selection of variables across outcomes may be sensitive to fatigue accrued during intensified periods of competition with youth soccer players. As a result, further research is required to identify physiological and methodological factors that may influence any temporal changes.

Previous research conducted with rugby league players suggests that an athlete's fitness profile may influence recovery during standard competitive schedules [15] and intensified periods of competition [4, 16]. Johnston et al. [4] reported that student rugby league players with greater high-intensity endurance recovered at a faster rate following match-play. Similarly, Johnston et al. [16] reported that stronger junior rugby players demonstrated less muscle damage post-match across a four-day, five-game tournament despite experiencing greater internal and external loads as assessed by RPE, high-speed running distance and number of collisions. The authors also found that those with greater high-intensity running endurance were able to cover greater distances at high and moderate speeds and maintain physical output throughout the tournament, whereas players with lower high-intensity running endurance exhibited trends of reduced physical output [16]. At present, few studies have assessed the effects of fitness variables such as strength and endurance on fatigue experienced during intensified periods of competition in youth soccer. Greater knowledge in this area may assist coaches with prioritising physical development prior to intensified periods of completion and identify outcome measures that are sensitive to fatigue accrued during such periods. Therefore, the purpose of this study was to quantify the temporal effects of an intensified period of competition in youth soccer players and assess whether strength or endurance influenced responses.

METHODS

Experimental Approach to the Problem

Data from an annual international competition were collected across two consecutive years to assess the response of elite youth soccer players to intensified periods of competition. Objective and subjective measures of fatigue were collected throughout the five-day international tournament using CMJ tests, quantification of high-intensity activity from match derived GPS data and responses to a perceptual wellness questionnaire. Player strength and endurance were assessed immediately prior to competition using a 5-repetition maximum (5RM) back squat test and the Yo-Yo intermittent recovery level 2 test (YYIRTL2), respectively. The primary aims of the study were to determine the temporal response of outcome measures across the tournament and identify whether initial fitness levels presented an interaction effect. Combining the data across two consecutive years increased sample size and precision of analyses.

Subject Information

Data were collected from two (n_1=18, n_2=18) under-16 male youth academy soccer teams (combined groups: age = 15.0 ± 0.7 yrs, height =172.7 ± 9.0 cm and mass = 61.7 ± 10.2 kg) comprising a range of outfield playing positions. Data were collected from two successive squads at annual soccer tournaments. Both competitions comprised six modified pre-season matches over five consecutive days with group stage matches played over the first three days of competition (2 x 25 min, 5 min half-time interval), the quarter- and semi-finals played on the fourth day (2 x 30 min, 5 min half-time interval) and the final played on the fifth day (2 x 30min, 5 min half-time interval). Results from both tournaments are presented in Tables 1-2. The location of the international tournament was consistent for both years as was accommodation and daily nutritional intake. Total air distance between the players home training ground and tournament location was 421 miles. No systematic recovery protocols were implemented during the tournaments. Written informed consent was obtained from participants and guardians, with ethical approval obtained by the Robert Gordon University School of Health Sciences Ethics Review Group.

Interventions and Outcome Measures

Identical data collection procedures were employed across both years. Baseline measures of lower body strength and high-intensity endurance were collected three days prior to competition through performance of a 5RM back squat test and the YYIRTL2, respectively. Players were fully familiarised with the tests as part of their continued performance profiling. The 5RM back squat test was performed with free weights and an Olympic barbell. Players performed an initial warm-up set at 50% of their predicted 5RM and then performed an additional three warm-up sets with progressively heavier loads. Based on the final warm-up set a suitable 5RM test load was selected. If successful, subsequent heavier testing loads were applied each with a three-minute recovery period and the load increased by a minimum of 5 kg until each player reached their 5RM [17]. High-intensity endurance was assessed using the YYIRTL2 as the test has been established as a valid and reliable assessment of endurance capabilities in soccer players [18].

During competitions objective and subjective indicators of fatigue were collected. Perceived wellness of players was assessed each morning, pre-breakfast, through a commonly used psychometric questionnaire for athletes [19]. The questionnaire comprised five items relating to: 1) perceived fatigue; 2) sleep quality; 3) general muscle soreness; 4) stress levels; and 5) mood. Each item was scored from 1 to 5 on a scale with 0.5 increments (with 1 representing the lowest measure of wellness and 5 representing the highest measure of wellness). Overall well-being was then determined by summing the scores from the five items. An objective assessment of physical performance was made by measuring CMJ height and power. Two sets of three repetitions were performed with the highest displacement and power value measured selected for further analysis. Displacement and power values were obtained with a single linear position transducer (Gymaware, Kinetic Performance Technology, Australia) using protocols previously shown to produce valid measures of peak power and jump height during jumping movements [20]. The CMJ test occurred immediately after the morning wellness questionnaire and began with a warm-up which included mobility and activation exercises that increased in intensity. During CMJ attempts the cable of the position transducer was attached to a wooden dowel positioned across the posterior aspect of the shoulders. The dowel also removed arm swing from the jumping action. The players were instructed to initiate the movement from an erect posture and to jump for maximum height whilst maintaining contact between the dowel and shoulders. CMJ height and mean power were selected as outcomes as both measures are commonly used to monitor athletes and their response to activity and have been shown to be reliable measures of neuromuscular fatigue in athletic populations [21, 22]. Players were familiarised with the wellness questionnaire and CMJ as these were standard monitoring measurements used on a daily basis throughout the season.

During each match, players wore commercially available GPS units (STATSports Viper, Northern Ireland) encased within a neoprene vest. Doppler GPS signals were collected at a frequency of 10 Hz with no data omitted due to poor satellite availability. Research conducted with similar GPS devices have been shown to produce valid and reliable estimates of instantaneous velocity during soccer-specific activities [23-26]. The GPS metrics selected to assess potential effects of fatigue on game-play included distance covered per minute ($m.min^{-1}$) and high-intensity running (13.1 to 16km.h^{-1}) per minute ($Hir.min^{-1}$). These metrics are commonly used and have featured in previous research investigating running performance in youth soccer matches [27].

Statistical Analysis

To account for covariances between observations made on the same player and unbalanced data due to player selection for each game, linear models with fixed and random effects were applied. Diagnostics on within-group and random effects residuals revealed no concerns for associated mixed model assumptions. The effects of time and fitness (strength and high-intensity endurance) were assessed with time entered as a categorical variable and fitness level measured by 5RM test scores and YYIRTL2 distance entered as covariates. Main and interaction effects were assessed using generalized likelihood ratio tests and the appropriate standard chi-squared asymptotic reference distribution. Statistical analyses were conducted using the lme4 package in the statistical environment R [28] [25]. Effect sizes were obtained by calculating generalized eta squared values (η_G^2) due to repeated measures data collection. Based on the recommendations of Bakeman [29], η_G^2 threshold values of .02, .13 and .26 were used to categorise effects as small, medium and large, respectively.

RESULTS

No significant main effects of time were found for CMJ height ($\chi^2_4 \leq 5.3$; $p \geq .262$) or power ($\chi^2_4 \leq 2.3$; $p \geq .688$) across both years. Group averages and standard deviations obtained across competitions for CMJ variables are presented in Table 3. Overall, results obtained for subjective measures (Figure 1) were consistent, with significant main effects of time obtained across both years for general muscle soreness ($\chi^2_4 \geq 19.6$; $p < .001$), stress levels ($\chi^2_4 \geq 12.7$; $p \leq .013$) and total summed score ($\chi^2_4 \leq 9.6$; $p \leq .048$). Pooling of data identified a large effect of time for general muscle soreness (η^2_G= .26) and moderate effects for stress levels (η^2_G= .13) and total summed score (η^2_G= .16). The subject's direct perception of fatigue remained consistent across both years with no significant main effect of time (χ^2_4 = 2.8; p = .584). In general, perceptions of sleep quality remained consistent across each tournament, however, a large reduction in initial sleep quality in the first year led to a significant but small effect of time (χ^2_4 = 7.2; p = .007; η^2_G= .08). Divergent results were obtained across years for overall mood with no significant main effect of time obtained during the first year (χ^2_4 = 3.8; p = .439) and a significant (χ^2_4 = 30.0; p < .001) and large effect (η^2_G= .27) obtained during the second year. Analysis of the results revealed a U-shape with the largest values obtained at the beginning and end of the second competition (Figure 1).

Consistent results were obtained for GPS data collected across both years (Figure 2). Significant ($\chi^2_4 \geq 22.3$; p < .001) and large effects ($\eta^2_G \geq .26$) of time were identified for metres per minute with both years exhibiting U-shape patterns. Similar profiles were also obtained for high-intensity metres per minute with significant main effects of time ($\chi^2_4 \geq 17.7$; $p < .003$) and a large effect obtained in the first year (η^2_G= .26) and a moderate effect (η^2_G= .16) obtained in the second year.

Interaction and main effects of strength and high-intensity endurance were consistent across both years for all variables assessed and therefore data were pooled for final analyses. No significant interaction effects were obtained for strength ($\chi^2_5 \leq 5.5$; $p \geq .360$) or high-intensity endurance ($\chi^2_5 \leq 5.0$; $p \geq .415$) for any of the CMJ or GPS related variables. In contrast, significant main effects of strength were found for CMJ height (χ^2_1= 5.6, p=.018; η^2_G= .18) and power (χ^2_1=7.0, p=.008; η^2_G= .29), indicating that stronger individuals produced on average higher values. Similarly, significant main effects of high-intensity endurance were found for metres per minute (χ^2_1=3.7,p=.050; η^2_G=.19) and high-intensity metres per minute (χ^2_1=8.0,p=.005; η^2_G= .19), demonstrating that players with greater fitness level achieved on average higher values.

DISCUSSION

The results of this study demonstrate that objective and subjective measures used to monitor fatigue of youth soccer players during intensified periods of competition display distinct temporal patterns. In general, results identified that selected GPS match play variables and perceptual measures of wellness exhibited changes across the period, whereas acute tests of muscle function in the form of CMJ height and power remained constant. Temporal patterns observed for most variables were consistent across the two annual competitions, thus providing support that results obtained were reliable. GPS match play variables exhibited curvilinear responses with both metres per minute and high-intensity metres per minute progressively decreasing across the tournament before returning (or exceeding) to initial levels for the final two games. As to be expected, greater variation in subjective measures of well-being were obtained across the two annual competitions. However, consistency was achieved for those subjective measures demonstrating progressive decreases across the competition which included perceived general muscle soreness, stress levels and total summed score for the questionnaire. The results also demonstrated that players' initial fitness levels including strength and high-intensity endurance had no effect on the temporal response of the outcomes measured. Finally, our results demonstrate that players who performed better in baseline strength testing recorded higher CMJ scores on average, and those who performed better in baseline YYIRTL2 recorded higher metres per minute and high-intensity metres per minute during matches.

Results obtained in the present study are, in general, consistent with previous investigations monitoring fatigue over intensified periods of competition with other populations. Previous research conducted with professional rugby league players reported perceived increases in fatigue, muscle soreness and reduction in overall well-being following match play, with values remaining suppressed over 48 hours and returning to baseline levels within four days [19]. It is likely that the lack of sufficient recovery time between match play in the present study led to increased perceptions of muscle soreness and stress. McLean et al. [19] showed that optimal recovery of general muscle soreness following a match was affected by many variables including previous training and the extent of muscular damage during match play. The results obtained in the present study demonstrate that players' perception of muscle soreness can increase from game to game when insufficient recovery time is provided as is the case during most condensed soccer tournaments. Importantly, outcome measures that reflect progressive accumulation of fatigue throughout intensified periods of competition may be of use to practitioners that wish to implement recovery strategies by providing a monitoring tool. Inconsistent results were obtained across the two years for quality of sleep with data collected in the first year demonstrating a substantial reduction in quality on the first day of the tournament. Reductions in initial sleep quality were likely caused by the specific environmental circumstances created with international travel arrangements and sleeping accommodation. However, controlling for these effects can be troublesome in youth settings due to logistical and financial restraints.

In the present study, distance covered per minute and high-intensity running per minute demonstrated significant changes over the course of the competition. Both variables exhibited an approximate 20% decrease between game 1 and game 3, before returning to near baseline values for the final two games. In contrast, Johnston et al. [4] reported a consistent decrease in absolute and relative distances covered at high speeds (>17.1 $km.h^{-1}$) during an intensified period of competition with male rugby league players. However, Arruda et al. [1] reported similar initial decreases in a range of GPS metrics followed by return to baseline with soccer players similar in age to those presented here. There is potential for match play variables such as those collected in the present study to be influenced by playing ability and tactics employed by both teams. Future research may wish to assess GPS metrics alongside tactical and positional data to enhance understanding of the effect of playing style and tactics. An alternative explanation for the increase in GPS metrics in the latter stage of the competition may include psychological effects influenced by the opportunity to win trophies and greater perceived importance of matches played at the end of tournaments.

The findings that acute muscle function tested through CMJ height and power remained unchanged across the intensified period in both years contradicts results obtained by Johnston et al. [4] with student rugby league players. The authors reported significant decreases in vertical jump force and power following the players initial game with values remaining suppressed for the remainder of the tournament [4]. However, the sensitivity of CMJ tests to identify neuromuscular fatigue remains unclear. Research conducted by McNamara et al. [30] with elite junior cricket players, failed to demonstrate changes in CMJ height and power during a 10-day period of intensified competition despite cortisol and testosterone concentrations indicating players were in a catabolic state. As suggested by the authors, it is possible that the sensitivity of outcome measures to detect fatigue may be sport-specific, with collision sports (e.g. American football, Australian football, rugby) creating more pronounced neuromuscular effects [30]. A recent meta-analysis investigating the sensitivity of CMJ tests to identify neuromuscular status (i.e. fatigue and supercompensation) concluded that selection of outcome measures as well as choice of specific variables including whether the peak or mean is used can affect sensitivity [31]. Further research is therefore required to identify outcome measures and data processing strategies to best monitor neuromuscular fatigue for soccer players engaging in periods of intensified competition.

In agreement with previous research, the results of the present study demonstrated that stronger players exhibited greater power outputs and that players with greater high-intensity endurance were able to cover significantly greater high-speed distances in match play [15, 32]. Importantly, given the aims of this study, there were no significant interaction effects between time and strength or time and high-intensity endurance for any of the outcomes assessed. These results indicate for this population that differences in physical qualities such as strength and high-intensity endurance do not influence fatigue response as assessed using a range of objective and subjective outcomes across an intensified period of competition.

There are limitations and further considerations that should be highlighted from this research. Whilst the players were accustomed to travel including international travel for competition, a confounding effect on both perceptual and neuromuscular fatigue is possible. Similarly, whilst GPS metrics were selected as a measure of physical performance and used to infer the presence of physical fatigue, it is possible that players employed pacing strategies, which may be influenced by score, substitutions or tactics employed and thereby confounded results [33]. Previous research has shown high intensity running to be influenced by score line and substitutions, but not by match performance [33]. However, our findings show an increase in high-intensity running metres per minute in both the semi-finals and finals stage. It should also be noted that in both tournaments, the final was lost by 3 goals, which may have effected running performance in both fixtures. The effect of technical and tactical variables, and quality of team faced, were out with the scope of the current study, but with larger data sets controlling for contextual variables in games additional insights and control of confounding variables may be possible. Future research regarding intensified periods of competition may wish to assess technical and tactical measures of performance, as well as physical metrics to provide better understanding of the effect of neuromuscular and perceptual fatigue on performance.

CONCLUSIONS

The results from this study indicate that basic CMJ variables including displacement and power may not be sensitive to fatigue accrued by youth soccer players during condensed tournaments that are used frequently to develop players. Similarly, basic GPS variables may also lack sensitivity to identify fatigue, particularly in the latter stage of a tournament. Therefore, it is recommended that practitioners collect information on simple perceptual measures including general muscle soreness and stress levels. Across repeated tournaments practitioners can build data-sets profiling typical patterns of fatigue and subsequently identify specific individuals that may require implementation of active recovery or bespoke load management strategies. Future research may wish to statistically combine information across multiple variables to assess whether sensitivity to fatigue is enhanced.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript

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Table 1: Match results from 2016 tournament

Match	Stage	Result	Assessed Team Match Outcome	Day and Time of Match
1	Group Stage	2-2	Drew	2nd August (13:30)
2	Group Stage	4-1	Won	3rd August (15:00)
3	Group Stage	3-1	Won	4th August (11:40)
4	Quarter-Final	2-1	Won	5th August (11:15)
5	Semi-Final	2-0	Won	5th August (19:15)
6	Final	4-1	Lost	6th August (11:40)

Table 2: Match results from 2017 tournament

Match	Stage	Result	Assessed Team Match Outcome	Day and Time of Match
1	Group Stage	6-0	Won	1st August (10:30)
2	Group Stage	9-0	Won	2nd August (11:10)
3	Group Stage	6-0	Won	3rd August (12:20)
4	Quarter-Final	4-0	Won	4th August (11:30)
5	Semi-Final	3-0	Won	4th August (18:30)
6	Final	0-3	Lost	5th August (11:45)

Table 3: Baseline fitness values and jump data across tournaments: Mean (± SD)

Variable	2016 Season	2017 Season
5RM Squat (kg)	63 ± (14)	69 ± (11)
YYIR2 (m)	655 ± (170)	864 ± (243)
CMJ Height (m)	0.43 ± (0.06)	0.45 ± (0.05)
CMJ Power (W)	2620 ± (872)	2810 ± (657)

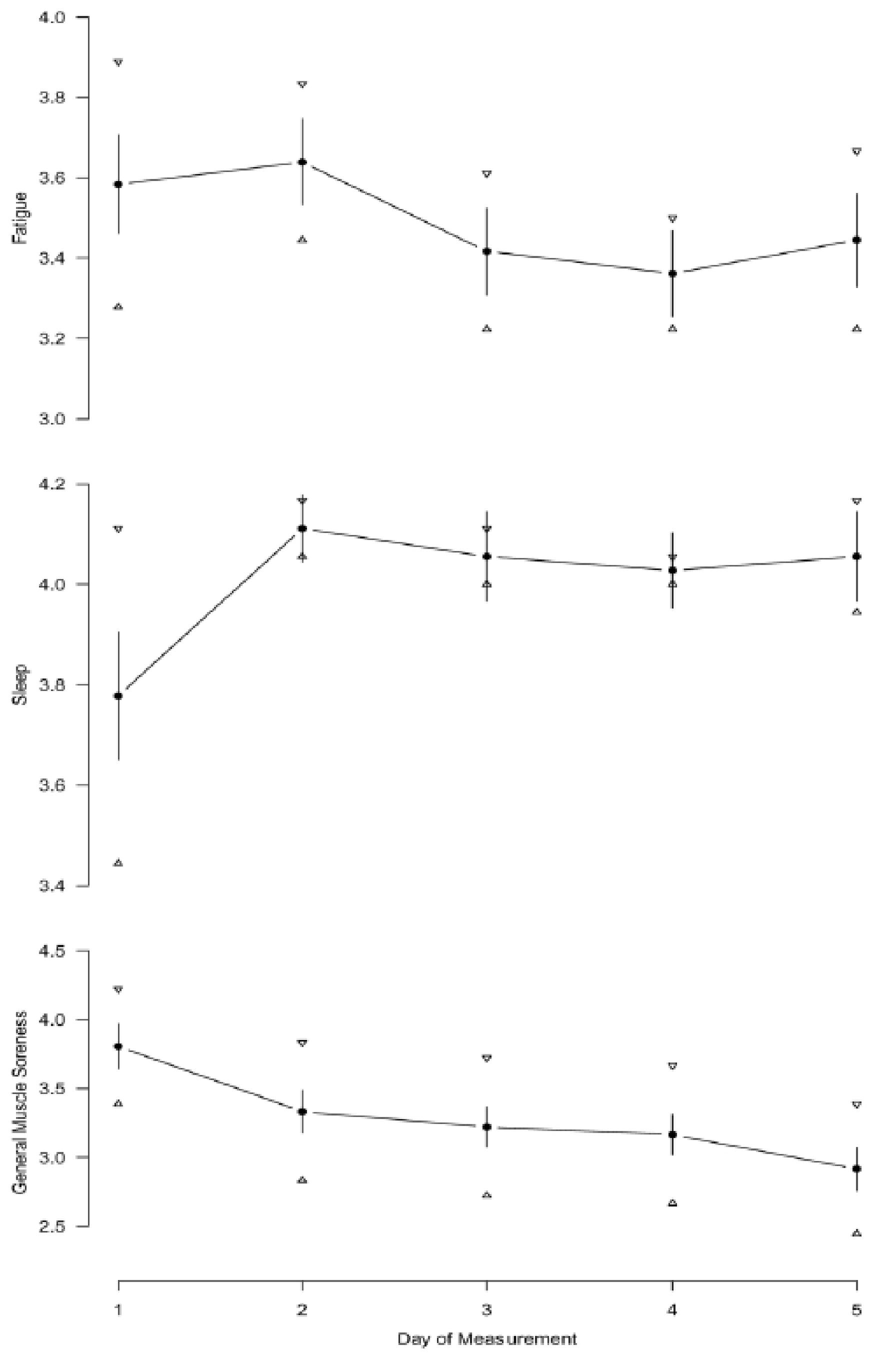

Figure 1A: Perceptual wellness scores across tournaments: Mean (± SE of mean)

Legend below: ● Mean from pooled data; △ Mean from 2016 data; ▽ Mean from 2017 data. Significant main effect for pooled data of day of measurement (* p<0.05, ‡ p<0.001).

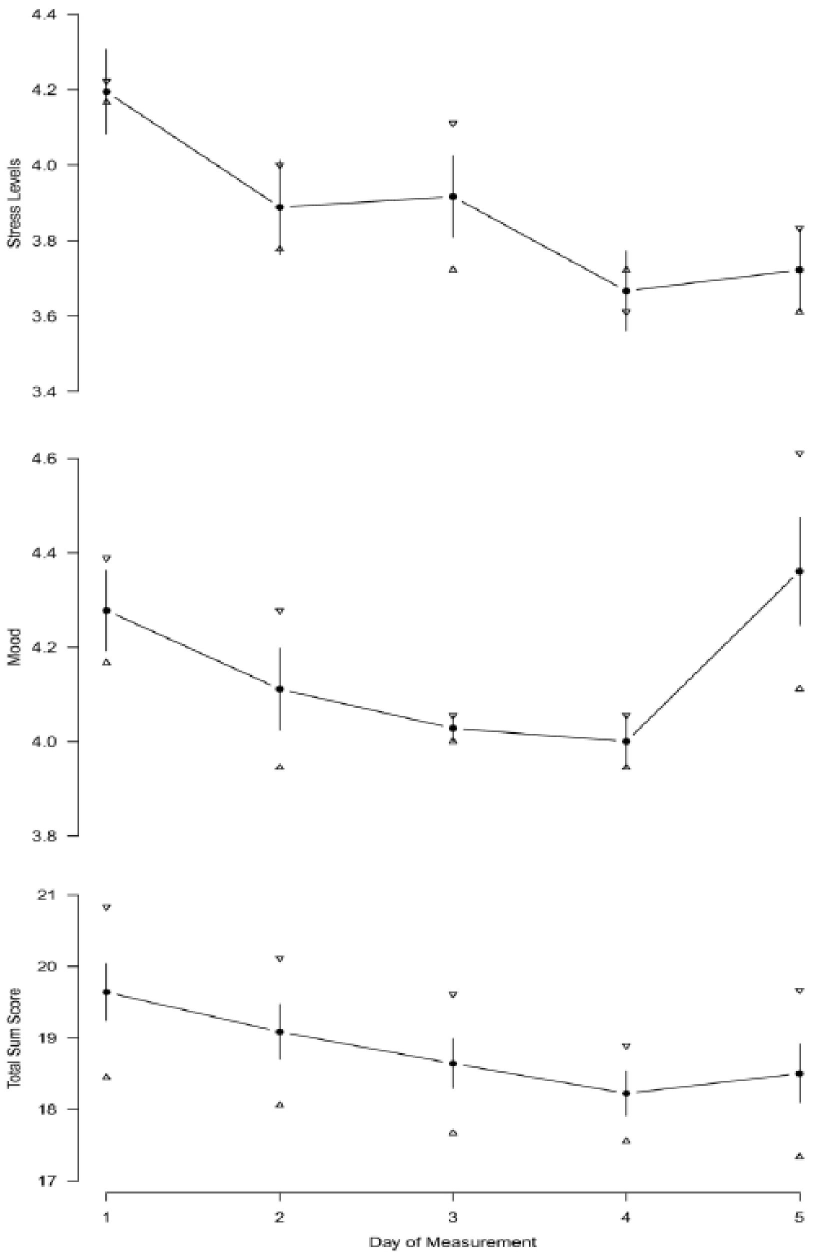

Figure 1B: Perceptual wellness scores across tournaments: Mean (± SE of mean)

Legend below: ⬤ Mean from pooled data; △ Mean from 2016 data; ▽ Mean from 2017 data. Significant main effect for pooled data of day of measurement (* p<0.05, ‡ p<0.001).

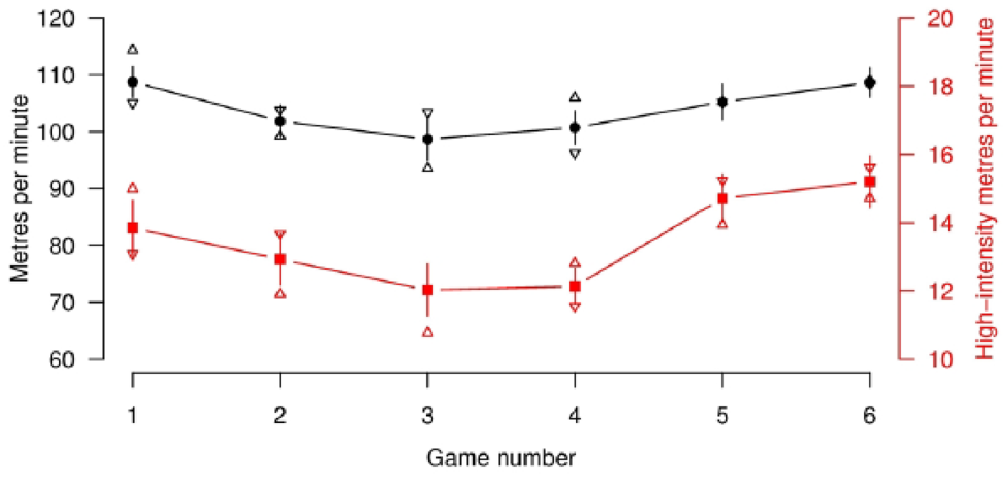

Figure 2: GPS variables across tournaments: Mean (± SE of mean)

Legend below: ● Mean metres per minute from pooled data (left axis); ■Mean high-intensity metres per minute from pooled data (right axis); △ Mean from 2016 data; ▽ Mean from 2017 data. Significant main effect for pooled data of day of measurement (‡ $p<0.001$).