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Kilduff, L. Measuring Recovery: An Adapted Brief Assessment of Mood (BAM+) Compared to Biochemical and Power Output Alterations. *Journal of Science and Medicine in Sport*

http://dx.doi.org/10.1016/j.jsams.2016.09.012

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Accepted Manuscript

Title: Measuring Recovery: An Adapted Brief Assessment of Mood (BAM+) Compared to Biochemical and Power Output Alterations

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PII:	S1440-2440(16)30212-2
DOI:	http://dx.doi.org/doi:10.1016/j.jsams.2016.09.012
Reference:	JSAMS 1398
To appear in:	*Journal of Science and Medicine in Sport*
Received date:	14-4-2016
Revised date:	12-7-2016
Accepted date:	7-9-2016

Please cite this article as: Shearer David A, Sparkes William, Northeast Jonny, Cunningham Daniel J, Cook Christian J, Kilduff Liam P.Measuring Recovery: An Adapted Brief Assessment of Mood (BAM+) Compared to Biochemical and Power Output Alterations.*Journal of Science and Medicine in Sport* http://dx.doi.org/10.1016/j.jsams.2016.09.012

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Measuring Recovery: An Adapted Brief Assessment of Mood (BAM+) Compared to Biochemical and Power Output Alterations

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Word Count = 2995

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Abstract

Objectives: Biochemical (e.g., creatine kinase (CK)) and neuromuscular (e.g., peak power output (PPO)) markers of recovery are expensive and require specialist equipment. Perceptual measures are an effective alternative, yet most validated scales are too long for daily use.

Design: This study utilises a longitudinal multi-level design to test an adapted Brief Assessment of Mood (BAM+), with four extra items and a 100mm visual analogue scale to measure recovery.

Methods: Elite under-21 academy soccer players (*N* = 11) were monitored across five games with data (BAM+, CK and PPO) collected for each game at 24 hours pre, 24 hours and 48 hours post-match. Match activity data for each participant was also collected using GPS monitors on players.

Results: BAM+, CK and PPO had significant ($p < .05$) linear and quadratic growth curves across time and games that matched the known time reports of fatigue and recovery. Multi-level linear modelling (MLM) with random intercepts for 'participant' and 'game' indicated only CK significantly contributed to the variance of BAM+ scores ($p < .05$). Significant correlations ($p < .01$) were found between changes in BAM+ scores from baseline at 24 and 48 hours post-match for total distance covered per minute, high intensity distance covered per minute, and total number of sprints per minute. *Conclusions:* Visual and inferential results indicate that the BAM+ appears effective for monitoring longitudinal recovery cycles in elite level athletes. Future research is needed to confirm both the scales reliability and validity.

Keywords: Perception, Fatigue, Enzymes, Response, Overtraining,

Measuring Recovery: An Adapted Brief Assessment of Mood (BAM) Compared to Biochemical and Power Output Alterations

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The competition schedule of elite team sport athletes makes them susceptible to under-recovery game-to-game [1, 2]. Cumulative fatigue causes overtraining [3], injury [4], and burnout [5], and consequently monitoring recovery is important for elite sport programmes. Perceptual measures of recovery have been used to monitor recovery in elite athletes[6, 7]. Often their use compliments physiological measures (e.g. biochemical) which are expensive and use specialist equipment. In elite sport, daily monitoring is necessary to track the impact of training and competitions. Longer self-report measures (Profile of Mood States (POMS)[8] and the Multicomponent Training Distress Scale [9]) will likely have higher refusal rates than shorter options[10]. Therefore, athlete engagement with self-report monitoring can be less than other aspects of recovery deemed more important (e.g., socialising with friends)[11].

Short measures of recovery, such as the Total Quality Recovery Scale [12] (TQRS) and the Recovery Cue [13] have been proposed. However, neither encompass specific elements of the mood disturbance spectrum (e.g., vigor, anger) which shows a consistent dose response relationship with training stress [14, 15] and have been used to monitor fatigue in elite athletes[16]. The Brief Assessment of Mood (BAM)[17] measures mood disturbance using six items representing each factor from the POMS. Shearer et al.,[7] used the BAM alongside neuromuscular and endocrine markers of fatigue in elite rugby union players, finding mood disturbance and energy index significantly correlated with power output. Shearer et al concluded the BAM was useful to monitor recovery in elite athletes, but with specific limitations. First, although mood has a consistent relationship with fatigue and recovery [18] other recovery factors (e.g., sleep quality, perceived stress, motivation) are not included in the scale. Second, the BAM used a five-point likert scale which participants felt was not sensitive enough to reflect their mood [7]. Third, the scale was used across the pre-game to post-game of one match, so was not tested beyond the acute game response. Finally, no direct measures of match activity (e.g., GPS) were made[1].

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The overall aim of the current study was to examine the longitudinal relationships of the BAM+ compared to concurrent measures of peak power output (PPO) and Creatine Kinase (CK). The study also aimed to address the limitations of Shearer et al [7]. First, four further items were added to the BAM (herein referred to as BAM+) to measure psychological capacity for stress (confidence and motivation) and physical recovery (muscle soreness and sleep quality) [12]. Second, the likert scale was replaced with a 100mm visual analogue scale, as used in other fatigue and pain-related research [19, 20]. Third, to track chronic game load, data was collected 12 hours before, and 24 and 48 hours after five consecutive competitive matches. Finally, because of the known reciprocal relationship between match activity and physical and psychological response[1], match activity was measured using GPS.

Research has demonstrated a consistent quadratic recovery profile from pre- to post-competition using physiological markers (e.g., neuromuscular power output[21], cortisol[14], and creatine kinase[22]) and measures of perceptual recovery [6, 7]. Therefore, for hypothesis one, all dependent variables (i.e., BAMS+, CK, and PPO) were expected to exhibit significant changes matching this quadratic profile of recovery [23] across all 5 games[1]. For hypothesis two, it was expected significant variance in scores from the BAM+ would be explained by concurrent measures of CK, and PPO. Finally, it was expected changes in BAM+ scores from baseline would correlate with similar match activities to those correlated with CK and PPO.

Method

Professional soccer players (N=11) who played in outfield positions for a Premier League under-21 soccer team volunteered for the study. Player made varying numbers of appearances (i.e., 3 ± 2) during the study due to coach selections for each game. Data are presented for players who played more than 60 minutes of a match and 5 games were observed in total. Altogether, 35 individual observations of match performance were obtained across the

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5 games (game 1 = 9, game 2 = 6, game 3 = 6, game 4 = 8, game 5 = 6). All players were healthy, injury-free and in full-time training at the time of the study. Players were in the maintenance phase of their training cycle while undertaking individual resistance training programs and team-based conditioning sessions.

Perceptual recovery was measured using a 10-item scale (BAM+) that comprised 6 original items from the Brief Assessment of Mood[17], plus additional items to measure confidence, motivation, muscle soreness, and sleep quality. Each item was worded to allow participants to express how they felt concerning the construct of interest. Example items included “How tense do you feel?” and “How well do you feel you have slept?”. Participants responded using a 100mm visual analogue scale anchored with “not at all” and “extremely”. Participants were instructed to place a vertical line along the scale at the point that described how they felt at that moment. From the ten items a recovery score was calculated by subtracting the mean score for the negatively associated items from the positively associated items. The impact of competition load was manifested in a reduced score that indicated compromised readiness to perform as per equation 1.

$$\frac{\left(\text{vigor} + \text{sleep quality} + \text{confidence} + \text{motivation}\right)}{4} - \frac{\left(\text{Anger} + \text{confusion} + \text{tension} + \text{depression} + \text{fatigue} + \text{muscles soreness}\right)}{6}$$

Cronbach alpha scores over all three time points for the four positive ($\alpha = 0.65$) and six negative items ($\alpha = 0.82$) indicated reasonable internal consistency and that items were grouped correctly.

A Kistler portable force platform with built-in charge amplifier (type 92866AA, Kistler Instruments Ltd, Farnborough, UK) was used to measure ground reaction force time history of the counter movement jump (CMJ). A sample rate of 1000 Hz was used for all jumps and the

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platform's calibration was confirmed pre and post testing. Power was calculated using standard procedures established in previous investigations [24, 25]. Test-retest reliability (ICC) for PO is 0.979.

Creatine kinase was measured using whole blood samples collected at the training ground. After immersing the hand in warm water, capillary blood samples (120μl) were obtained from a fingertip and stored on ice in EDTA prepared collection tubes (Microvette 500, Sarstedt, Numbrecht, Germany) before being centrifuged at 3,000 revolutions per minute for 10 minutes (Labofuge 400R; Kendro Laboratories, Langenselbold, Germany). Plasma samples were then stored at -70 C before being analyzed for CK activity using commercially available kits (CK-NAC, ABX Diagnostics, Northampton, United Kingdom) on a Cobas Mira spectrophotometer (ABX Diagnostics, Northampton, United Kingdom). Samples were measured in duplicate (3% coefficient of variation) and recorded as a mean.

To measure match activity players wore 10 Hz GPS units (Viper pod, STATSports, Belfast, UK) positioned on the upper torso within a specifically designed garment to reduce movement artefacts[26]. Measurement began immediately before pre-match warm-up (~40 min before kick-off) and players wore the same GPS device for each match to avoid inter-unit variation. After each match, raw data files were analyzed and six indices of physical performance were used based on previous research[1]. The variables presented relate to coverage of total, high intensity, sprint and high speed running distance and the number of sprints. Operational definitions for these variables are as per the manufacturer's website (http://statsports.com/technology/viper-software/).

Ethics approval in accordance with the World Medical Association was provided by the Ethics Advisory Board of Swansea University and all participants provided informed consent. Twelve hours before each match, baseline scores for the BAM+, samples of whole blood, and measurements of CMJ (which were preceded by a standardized dynamic warm-up)

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were obtained. These measure were repeated at 24 hours and 48 hours post-match at the same time of day (± 60 mins) as baseline measures (Figure 1). When completing the BAM+ players were reminded to answer every question accurately, and not confer with other players concerning their answers. A research team member was present at all times to ensure this was adhered to and answer queries concerning the questionnaire. Players were assured their responses would not be used for the purposes of selection but consented for their data to be shared within the coaching and sport science support team for the purposes of monitoring fatigue.

Data was screened using Kolmogorov-Smirnoff tests (i.e., $p > .05$) and visual inspection of histogram plots and deemed normally distributed. Multilevel modelling (MLM) was used to examine the longitudinal relationships between BAM+ scores, PPO, and CK. Initially growth curve models were tested for each variable measured to distinguish the nature of change over time (e.g., linear v polynomial). Then, using BAM+ scores as the dependent variables, PPO and CK were tested as predictors. An identity and diagonal covariance structure was used to examine random effects and repeated measures respectively. "*Subject*" and "*Game*" were included as level 2 and level 3 grouping variables to denote how dependent variable scores were nested first within subjects and then within individual games and were both included as random intercepts in the model (i.e., modelling for different start values for each individual/game). The significance and relative contribution of all variables to the total variance BAM+ was examined using F ratios ($p < 0.05$) and beta values ($p < 0.05$). Finally, a 1-tailed Pearson's correlation was used to examine the relationship between 6 GPS measured match activities and changes in BAM+, PPO and CK scores from baseline at 24 and 48 hours post-match[1].

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Results

The growth curve for BAM+ showed an significant negative linear trend within and across the 5 games ($\beta = -9.69$, $t = -5.06$, $p < 0.001$, CI [-13.55, -5.82]) with significant quadratic change throughout the same period ($\beta = 2.21$, $t = 4.60$, $p < 0.001$, CI [1.24-3.18]). This indicated an overall decrease in BAM+ from time 1 to 3 and across the 5 games with a simultaneous overall increase in the rate of change at this time (Figure 2). Scores for CK showed a significant linear increase within and across the 5 games ($\beta = 1236.31$, $t = 12.10$, $p < 0.001$, CI [1031.35, 1441.27]) with significant negative quadratic change throughout the same period ($\beta = -288.15$, $t = -11.21$, $p < 0.001$, CI [-339.73, -236.58]). This indicated an overall increase in CK from time 1 to 3 and across the 5 games with a simultaneous overall decrease in the rate of change across the same period. For PPO, scores indicated a significant negative linear trend in PPO within and across the 5 games ($\beta = -898.42$, $t = -7.43$, $p < 0.001$, CI [-1140.35, -656.49]) with significant positive quadratic change throughout the same period ($\beta = 208.63$, $t = 8.49$, $p < 0.001$, CI [159.20, 258.06]). This indicated an overall decrease in PPO from time 1 to 3 and across the 5 games with a simultaneous increase in the rate of change across the same period (Figure 2). As linear and quadratic components of time were significant in the growth curves for all variables they were retained for the full model to examine the predictive contribution of CK and PPO to changes in BAM+ scores.

A multi-level analysis with BAM+ as the dependent variable, and CK, PPO, linear and quadratic time as predictors indicated significant contributions of all predictors apart from PPO ($p = 0.058$) (see Table 1). Results indicated that a 1 standard deviation increase in BAM+ percentages was matched by a 0.3% significant reduction in CK, and a 0.2% decrease in PPO. Estimates of covariance parameters indicated that initial (i.e., intercept) BAM+ scores varied significantly as a function of both individual subject scores and game ($\beta = 1.66$, Wald $Z = 2.30$, $p < 0.05$) highlighting the importance of modelling the data in a multilevel fashion.

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Pearson's correlations between GPS measured match activities and changes in BAM+ scores from baseline (ΔBAM) indicated that at 24 hours post-match, total distance per minute ($p = 0.002$), high intensity distance per minute ($p = 0.004$), and total sprints per minute ($p = 0.001$) were moderately related to ΔBAM+ scores. At 48 hours, post-match total distance per minute ($p = 0.001$), high intensity distance per minute ($p = 0.009$) and total sprints per minute ($p = 0.001$) were related to ΔBAM+ scores. Although changes in CK and PPO from baseline correlated with a number of match activity measures, only CK's correlation with high intensity distance per minute at 24 hour post game matched that of BAM+ (Table 2).

Discussion

This study addressed the limitations of the BAM for measuring recovery in elite athletes[7] and examined the longitudinal recovery pattern of elite academy football players over 5 competitive matches. CK and PPO were measured concurrently alongside BAM+ at 12 hours before, and 24 and 48 hours post-match. In addition, GPS match activity was correlated to changes in BAM+ scores from baseline at 24 and 48 hours post-match. Changes in all variables matched the expected pattern indicative of recovery within and across games[1], indicating concurrence between scores. Growth curves indicated significant linear and polynomial changes for BAM+, CK, and PPO. Specifically, significant linear decline and a positive quadratic curves over time and games were observed for BAM+ and PPO scores. In contrast, CK scores showed a significant linear increase and a negative quadratic curve over time and games.

The longitudinal relationship between BAM+ scores, CK, and PPO indicated CK significantly contributed to the variance in BAM+ scores, while PPO neared significance. This relationship between perceptual and physiological markers of fatigue is now well established [6, 7, 14]. Modelling random intercepts of 'subjects' and 'games' highlighted significant

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differences in individual responses to playing load and the unique nature of each game in terms of measured variables. Between match variability has been found before[2], however little research accounts for inter-individual variability and this study highlights the importance of using linear mixed modelling to do this. Finally, significant correlations were found between changes in BAM+ scores from baseline at 24 and 48 hours post-match and total distance per minute, high intensity distance per minute, and number of sprints per minute. Although significant correlations were found for CK and PPO with respect to specific match activity, only the correlation of CK at 24 hour post-match with high intensity distance per minute matched those of BAM+ .The BAM+ appeared to correlate well with the 'per minute' normalised measures of match activity, whereas CK and PPO did not. Theses normalised measures represent how hard a player worked overall and might be more accurately judged by players than absolute values. Therefore, as a perceptual measure of recovery it might be expected that the BAM+ correlated with these match activities in particular, and that BAM+, CK and PPO measure different but equally valid components of recovery.

The current study extends the methodology of Shearer et al[7]. Specifically, four items were added that measured factors related to psychological capacity for stress and physical aspects of recovery[12], and a 10cm visual analogue scale was used to allow participants to accurately reflect their perceptions. While the impact of these changes was not measured directly, their inclusion broadens the scope of the measure to monitor recovery (i.e., not just mood based) and addressed the concerns of some athletes regarding scale sensitivity. Second, Shearer et al only demonstrated a classic recovery profile using the BAM for one match. This study has shown this profile is consistent over 5 matches. In addition, growth curve analyses for all variables indicated an increasingly diminished recovery profile from game 1 through game 5 indicative of cumulative stress. Finally, Shearer et al inferred game intensity from the nature of the competitive fixture, and total time played by participants. In this study specific

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match activities related to changes in BAM+ scores from baseline at 24hrs and 48hrs were examined. Although useful to understand how game load relates to changes in BAM+ scores, findings in this aspect of the study reflect commentary by Saw et al[27] who highlighted poor concurrence between objective and subjective markers of fatigue, despite finding that subjective markers are sensitive to both acute and chronic training load.

Although not significant, PPO approached significance and matched the observed pattern of change for BAM+ and therefore is included in our conclusions. Although BAM+ and PPO show a concurrent negative trend throughout the five games, the non-significant beta values for the covariate analysis indicates that overall there was a 0.2% decrease in PPO for every unit increase in BAM+. Although an insignificant and small decrease, this conflicts with the observable changes and those of the growth curve analysis. Had the sample size been larger a stronger case could have been made either way. While in longitudinal MLM *effective* sample size is a combination of the physical number of participants and the number of observations over time[28] more participants would have increased statistical power. There are precedents in the existing literature that use MLM and have similar sample sizes to that used here[29]. In addition, this limitation is balanced against the advantages of using elite participants, making data inference meaningful to elite sport. Future research should aim to build on these findings using larger numbers of elite athletes.

Conclusions

The results support previous research using mood and/or perceptual-based measures to monitor recovery [6, 15]. The BAM+ was sensitive to known physiological changes that occur in response to competition stimuli. As mood disturbance has a strong dose-response relationship with fatigue [15] it is an important component perceptual measurement tools. Given most other psychological measures of recovery that include mood or otherwise are too long and repetitive for daily use, the BAM+ represents a practically useful daily measure of recovery that

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encompasses mood, psychological capacity for stress, and aspects of physical recovery. It should be noted however, this was not an attempt to structurally validate the BAMS+, and future research with large sample sizes to allow for structural validation are recommended.

Practical Implications

- This adapted Brief Assessment of Mood (BAM+) tracks the known cycle of recovery associated with competition.
- BAMS+ provides a cheaper alternative to physiological measures of recovery
- It is recommended that a combined approach of both physiological and psychological measures of fatigue and recovery to reduce response bias associated with repetitive use.

Acknowledgements

We would like to thank the Knowledge Economy Skill Scholarship fund and Swansea City Football Club for the financial support of this project.
We would like to thank Prof Stephen Mellalieu (Cardiff Metropolitan University, UK) for his contribution to initial discussion regarding the BAM+ development.

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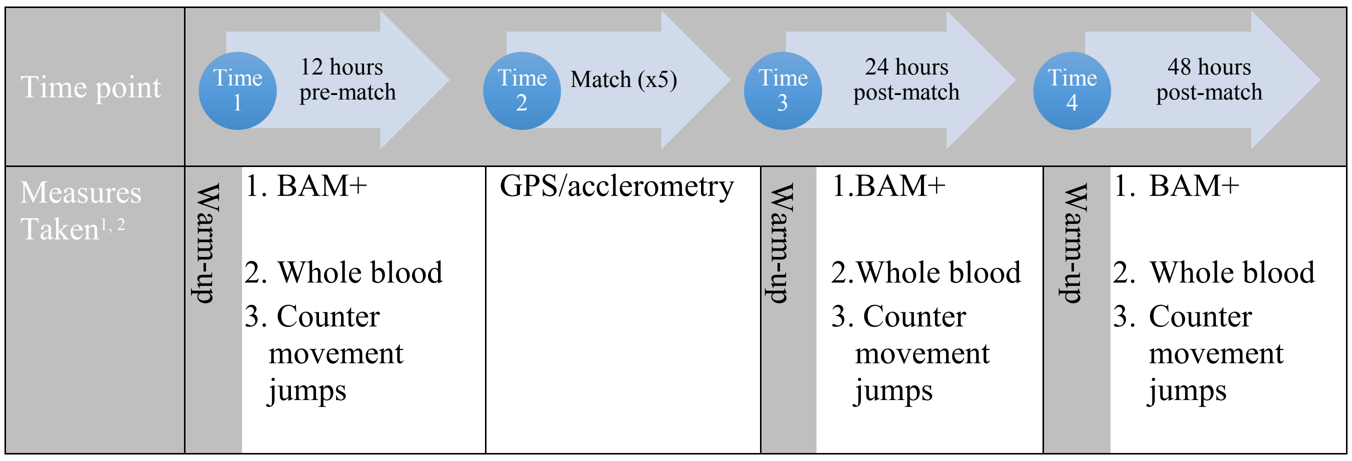
Figure 1. Gant chart representing timing and ordering of measures across the 5 matches



Time point	Time 1 12 hours pre-match	Time 2 Match (x5)	Time 3 24 hours post-match	Time 4 48 hours post-match
Measures Taken[1, 2]	Warm-up 1. BAM+ 2. Whole blood 3. Counter movement jumps	GPS/acclerometry	Warm-up 1.BAM+ 2.Whole blood 3. Counter movement jumps	Warm-up 1. BAM+ 2. Whole blood 3. Counter movement jumps

[1] Measures taken in chronological order as represented by numbered list and immediately one after each other.

[2] Same procedure followed identically for each of the 5 matches

Figure 2. Game-by-Game variations in BAM+, CK and PPO scores

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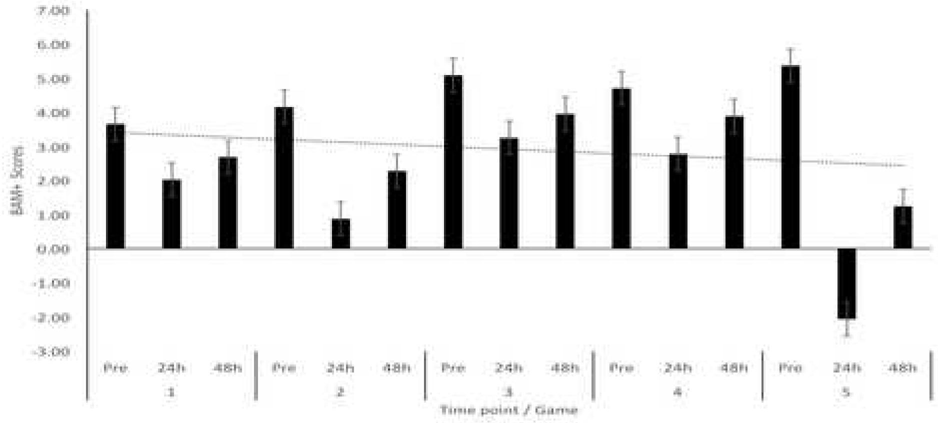

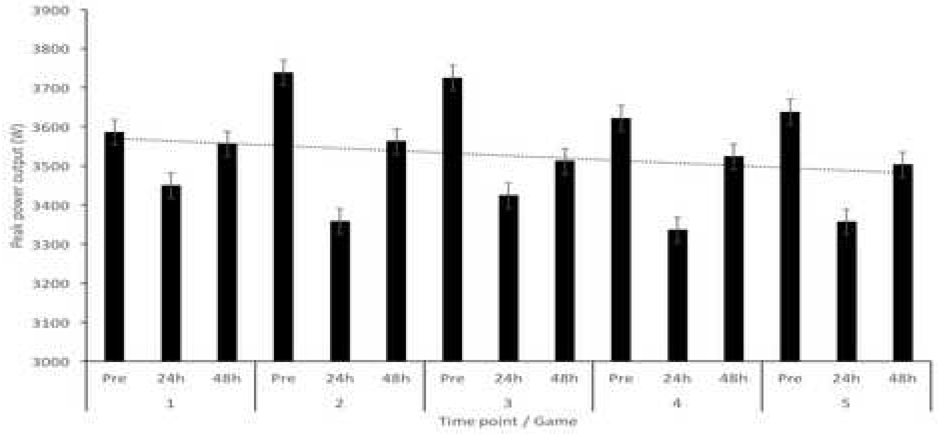

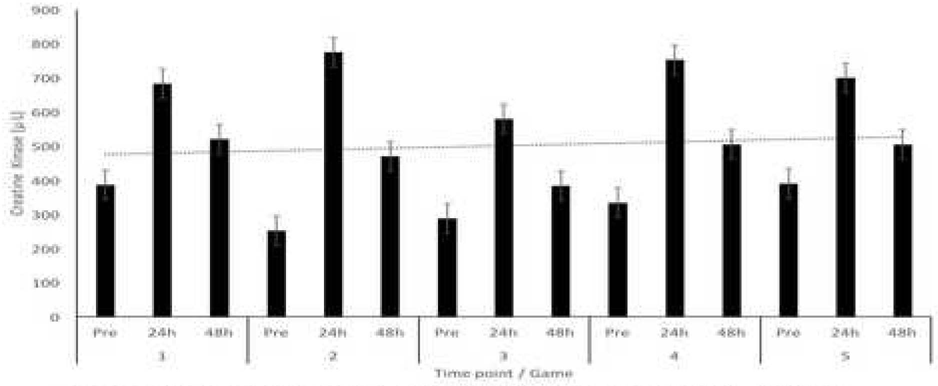

Note: Pre = 12 hours pre-match; 24h = 24 hours post-match; 48h = 48 hours post-match; BAM+ = Scores from Brief Assessment of Mood +

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Table 1. Beta estimates, significance and confidence intervals for each predictor related to BAM+ scores

				95% Confidence Interval	
	β	t	p	Lower Bound	Upper Bound
Intercept	16.731	4.564	.000	9.35	24.11
CK	-.003	-2.079	.041	-.006	-.0001
PPO	-.002	-1.967	.058	-.003	5.41 x 10^5
time	-7.280	-2.700	.009	-12.65	-1.91
Quad-time	1.648	2.533	.013	.35	2.94

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Table 2. Pearson's product moment correlation between match activities and changes (Δ) in BAM+, CK and PPO scores at 24hrs and 48hr post-match

	ΔBAM+		ΔCK		ΔPPO	
Match Performance Variable	+24 hr	+48hr	+24 hr	+48hr	+24 hr	+48hr
Total Distance covered	0.093	0.137	.590**	.482**	-.470**	-0.036
Distance covered per minute	-.474**	-.511**	0.007	-0.106	-0.047	-0.103
High intensity distance covered	-0.212	-0.167	.659**	.443**	-.422**	-0.214
High intensity distance covered per minute	-.441**	-.399**	.365*	0.145	-0.081	-0.227
Sprinting distance	-0.276	-0.2	.515**	.346*	-0.273	-0.208
Total number of sprints per minute	-.551**	-.490**	0.237	0.107	-0.094	-0.182

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

ACCEPTED MANUSCRIPT

RUNNING HEAD: Mood, Biochemistry and Power Measures During Recovery