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2019

### Subjective Wellness, Acute: Chronic Workloads, and Injury Risk in College Football

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#### Publication Details Citation

Sampson, J. A., Murray, A., Williams, S., Sullivan, A., & Fullagar, H. (2019). Subjective Wellness, Acute: Chronic Workloads, and Injury Risk in College Football. Faculty of Science, Medicine and Health - Papers: Part B. Retrieved from <https://ro.uow.edu.au/smhpapers1/1181>

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## Subjective Wellness, Acute: Chronic Workloads, and Injury Risk in College Football

### Abstract

Acute:chronic workload ratios (ACWRs) are associated with injury risk across team sports. In this study, one season of workload and wellness data from 42 collegiate football players were retrospectively analyzed. Daily 7:21 day exponentially weighted moving average (EWMA) ACWRs were calculated, and z-score fluctuations (“normal,” “better,” and “worse”) in sleep, soreness, energy, and overall wellness were assessed relative to the previous day ACWRs and considered as an interactive effect on the risk of noncontact injury within 0–3 days. Fifty-five noncontact injuries were observed, and injury risks were *very likely* higher when ACWRs were 2 SDs above (relative risk [RR]: 3.05, 90% confidence interval [CI]: 1.14–8.16) and below (RR: 2.49, 90% CI: 1.11–5.58) the mean. A high ACWR was *trivially* associated ( $p < 0.05$ ) with “worse” wellness ( $r = -0.06$ , CI:  $-0.10$  to  $-0.02$ ), muscle soreness ( $r = -0.07$ , CI:  $-0.11$  to  $-0.03$ ), and energy ( $r = -0.05$ , CI:  $-0.09$  to  $-0.01$ ). Feelings of “better” overall wellness and muscle soreness with collectively high EWMA ACWRs displayed *likely* higher injury risks compared with “normal” (RR: 1.52, 90% CI: 0.91 to 2.54; RR: 1.64, 90% CI: 1.10–2.47) and *likely* or *very likely* (RR: 2.36, 90% CI: 0.83 to 674; RR: 2.78, 90% CI: 1.21–6.38) compared with “worse” wellness and soreness, respectively. High EWMA ACWRs increased injury risk and negatively impacted wellness. However, athletes reporting “better” wellness, driven by “better” muscle soreness presented with the highest injury risk when high EWMA ACWRs were observed. This suggests that practitioners are responsive to, and/or athletes are able to self-modulate workload activities.

### Publication Details

Sampson, J. A., Murray, A., Williams, S., Sullivan, A. & Fullagar, H. H. K. (2019). Subjective Wellness, Acute: Chronic Workloads, and Injury Risk in College Football. *Journal of Strength and Conditioning Research*, 33 (12), 3367-3373.

1 RUNNING HEAD: Wellness, workload and injury risk

2  
3 **Subjective wellness, acute:chronic workloads and injury risk in college football**

4  
5  
6 **ABSTRACT**

7 Acute:chronic workload ratios (ACWR) are associated with injury risk across team sports. In  
8 this study, one season of workload and wellness data from forty-two collegiate football players  
9 were retrospectively analysed. Daily 7:21 day exponentially weight moving average (EWMA)  
10 ACWR were calculated, and z-score fluctuations (“normal” “better” and “worse”) in sleep,  
11 soreness, energy and overall wellness were assessed relative to the previous days ACWR and  
12 considered as an interactive effect on the risk of non-contact injury within 0-3 days.

13 55 non-contact injuries were observed and injury risks were *very likely* higher when  
14 ACWR’s were 2SD’s above (RR: 3.05, 90% CI: 1.14 to 8.16) and below (RR: 2.49, 90% CI:  
15 1.11 to 5.58) the mean. A high ACWR was *trivially* associated ( $p < 0.05$ ) with “worse” wellness  
16 ( $r = -0.06$ , CI: -0.10 to -0.02), muscle soreness ( $r = -0.07$ , CI: -0.11 to -0.03), and energy ( $r = -$   
17  $0.05$ , CI: -0.09 to -0.01). Feelings of “better” overall wellness and muscle soreness with  
18 collectively high EWMA ACWRs displayed *likely* higher injury risks compared to “normal”  
19 (RR: 1.52, 90% CI: 0.91 to 2.54; RR: 1.64, 90% CI: 1.10 to 2.47) and *likely* or *very likely* (RR:  
20 2.36, 90% CI: 0.83 to 674; RR: 2.78, 90% CI: 1.21 to 6.38) compared to “worse” wellness and  
21 soreness respectively.

22 High EWMA ACWR increased injury risk and negatively impacted wellness. However,  
23 athletes reporting “better” wellness, driven by “better” muscle soreness presented with the  
24 highest injury risk when high EWMA ACWR were observed. This suggests that practitioners  
25 are responsive to, and/or athletes are able to self-modulate workload activities.

26  
27 Key words: Sleep, Soreness, Fatigue, Internal load, External load, GPS Playerload

## 32 INTRODUCTION

33 American football is a physically demanding contact sport comprising substantial impact loads  
34 and intermittent bouts of high intensity activity (45, 46). Injury rates are correspondingly high  
35 and likely associated with the heavy contact loads, however >25% of injuries are attributed to  
36 preventable non-contact injury (8). In college football, athletes are typically engaged in 8-9  
37 hours/day of football related activities in addition to 3-4 hours/day in academic classes and  
38 home study. The varied injury risks observed across positional groups and with playing  
39 experience (relative to educational enrollment status) may yet be a consequence of diverse  
40 training and game demands (30). Monitoring, modifying and optimising workloads in college  
41 football in an attempt to reduce the number of these injuries is thus an essential player welfare  
42 practice (10).

43 Workload monitoring is indeed commonplace, with global positioning systems (GPS) and built  
44 in inertial measurement units (IMU) typically used in college football to quantify training and  
45 match workloads (37, 45-47). Across a range of contact team sports, including American  
46 college football, increased injury risks have consistently been observed when “spikes” in  
47 current (acute) relative to accumulated (chronic) GPS/IMU derived acute:chronic workload  
48 ratios (ACWR) are observed (7, 19, 37). The consistency of increased injury risk seen across  
49 the literature when high ACWR occur suggests the ratio has merit for workload monitoring  
50 practice. However, where absolute (%) risks are reported,  $\leq 25\%$  of athletes exposed to high  
51 and very-high ACWR actually suffer an injury (19), and low predictive capabilities have been  
52 observed (9, 29). In this regard, one should consider that many sports encompass a range of  
53 external training stressors (e.g. running, throwing, contact, resistance training, static work) that  
54 contribute to the total workload and it is important to recognise that increased injury risks do  
55 not arise from workload spikes *per se*, but from the stress associated with threats to homeostasis  
56 by separate and potentially multiplicative intrinsic and extrinsic disturbances (5).  
57 Correspondingly, it has been shown that athletes possessing greater fitness are less likely to  
58 sustain injury when exposed to ACWR spikes and recover more rapidly from competition  
59 induced workloads (20, 25, 27). Indeed, in American College football, whilst workload ‘spikes’  
60 are informative, some athletes are shown to be more robust and less susceptible to injury when  
61 workload spikes are observed (37).

62 A number of current studies have examined the multiplicative effects of combining external  
63 workload measures with consistently greater risks observed with low chronic workloads and a  
64 concurrently high ACWR (7, 37). Notably, Colby and colleagues report substantially increased  
65 injury risks with heavy non-sport activity and old lower limb pain (7). Pain is commonly  
66 reported amongst athletes and may reflect microtrauma associated with overuse injury (6).  
67 Considering the high prevalence of overuse injury (15), and reports of athletes frequently  
68 participating despite the presence of pain (36, 42), methods for monitoring player wellness are  
69 well justified. Indeed, subjective internal stress reports including soreness, sleep, stress and  
70 fatigue have been shown to reflect negative responses to high training loads and the frequency  
71 of high intensity activity and collisions in sport (33, 40, 43). However, we are unaware of any  
72 research that has assessed the effect of external workload “spikes” depicted by ACWR on an  
73 athletes subsequent internal self-reported wellness.

74 Considering quantitative data depicting the athletes internal stress response from wellness  
75 reports alongside fluctuating workloads in sport may also provide further insight into an  
76 athlete’s risk of injury. The current investigation will therefore assess the effect of fluctuating  
77 ACWR’s on self-reported wellness and examine ACWR-wellness interactions relative to the  
78 risk of injury in NCAA American college football.

79

## 80 **METHODS**

### 81 **Experimental approach to the problem**

82 Athletic workload and self-reported (subjective) wellness questionnaires collated over a full  
83 season (17 weeks) of NCAA Division 1 college football were retrospectively analysed.  
84 Previously a 7:21 day coupled ACWR calculated using an exponentially weighted moving  
85 average (EWMA) method with a 3-day injury lag period has shown the greatest associations  
86 with injury (37). Herein, 7:21 day EWMA ACWR were synchronised with wellness data  
87 reported the morning after 3 × weekly main field-training sessions. Any daily file missing self-  
88 reported wellness data was removed leaving 1807 aligned wellness/ACWR in-season data files  
89 (training days) in the analysis.

90

## 91 **Subjects**

92 Forty-two athletes competing for the same Division I-A American college football team (age:  
93  $20.5 \pm 1.2$  yr, mass:  $102.8 \pm 17.4$  kg, height:  $186.4 \pm 6.7$  cm) comprising 7 defensive backs, 8  
94 defensive linemen, 6 linebackers, 8 offensive linemen, 2 quarterbacks, 5 running backs, 5 wide-  
95 receivers and 1 tight-end were included in this study. Within this group 7 were Freshman, 7  
96 Juniors, 12 Sophmores and 16 were Seniors. All participants signed an informed consent form  
97 upon enrollment indicating that de-identified data collected as part of their athletic participation  
98 may be used for research purposes. Participants were specifically informed of the requirements  
99 of this study prior to data collection and all experimental procedures were approved by  
100 University human ethics committee's and Research Compliance Services.

## 101 **Procedures**

### 102 *Injuries*

103 Injuries were recorded and documented by the teams athletic training group and classified by  
104 incident; date; location; type; and mechanism. As per previous research, diagnoses made by  
105 athletic training staff were reviewed retrospectively and confirmed or amended by a sports  
106 physician (30). All non-contact injuries reported to medical staff in this investigation resulted  
107 in some form of withdrawal from practice or game-time and all were included in the analysis  
108 (regardless of ensuing time-lost or not on subsequent days) as this type of injury is considered  
109 largely preventable (12).

### 110 *Quantifying load*

111 Workloads were collected from global positioning systems (GPS) sampling at 10 Hz  
112 (Optimeye S5; Catapult Innovations, Melbourne, Australia) during the 3-week pre-season  
113 conditioning phase, all in-season 'on-field' workloads (comprising 3 x weekly conditioning  
114 sessions, 2 x weekly walk-through sessions) and game day. Data collected by this device is  
115 considered a valid and reliable reflection of the activities performed in team sports (21, 41).  
116 Only players with workload data from every type of session (pre-season conditioning, in-  
117 season conditioning and walk-through days) were included in the analysis. This decision was  
118 made in order to include a value for any 'missing' data files (typically due to a malfunctioning  
119 GPS unit) in the data. Herein, 37 "missing" pre-season (generalised conditioning) files were  
120 included relative to the players individual weekly pre-season average. During the in-season,

121 the individuals average specific to the missing session (GPS devices were typically only worn  
122 during one of the two weekly walk-through sessions and for 60 missing conditioning sessions),  
123 were added to the data set. Participants wore the same GPS unit in each session. Playerload™,  
124 a variable collected by tri-axial accelerometers within the device sampling at 100Hz and  
125 calculated within the manufacturer's software as; the square root of the sum of the squared  
126 instantaneous rate of change in acceleration within the three planes divided by 100 (OpenField  
127 1.11, Catapult Innovations, Melbourne, Australia) were used to quantify workloads. Daily  
128 exponentially weighted moving average (EWMA) ACWR's were retrospectively calculated by  
129 dividing the 7-day (acute), by the 21-day (chronic) workload (37).

### 130 *Subjective wellness*

131 Each days EWMA ACWR was aligned with wellness reported in a customized wellness  
132 questionnaire ~ 2 h before each field training session (11). No data was collected on, or the day  
133 after game day (rest day/day off). The questionnaire comprised three 5-point Likert scale  
134 questions on self-reported soreness (1 = terribly sore, to 5 = no soreness at all), sleep (1 = slept  
135 terrible, to 5 = excellent sleep) and energy (1 = no energy, to 5 = totally energized) and  
136 participants were familiarised with all scales. Overall wellness was calculated as the average  
137 of the summed soreness, sleep and energy scores for each athlete (1= poor wellness, to 5 =  
138 excellent wellness).

### 139 *Data analysis*

140 Z-score deviations relative to an individual's own mean or "normal" score were calculated and  
141 expressed as "better" ( $\geq 1$  higher than the mean) or "worse" ( $\leq 1$  lower than the mean) to  
142 determine a meaningful change in wellness, sleep, soreness and energy. The daily ACWR were  
143 aligned with the associated self-reported wellness scores (e.g. calculated ACWR following  
144 Monday's session were aligned with self-reported wellness z-score scores recorded on Tuesday  
145 morning) providing three ACWR/wellness data points per week.

### 146 **Statistical Analysis**

147 All estimations were made using the *lme4* package (4) with *R* (version 3.3.1, R Foundation for  
148 Statistical Computing, Vienna, Austria). The subjective wellness reports were assessed for  
149 normality and appropriate parametric or non-parametric correlations performed. A generalized

150 linear mixed-effects model (GLMM) with the complementary log-log link function was used  
151 to model the association between ACWR, wellness measures, and injury risk in the subsequent  
152 three-day period. ACWR and wellness measures were modelled as fixed effect predictor  
153 variables, and player identity was the random effect. A multiplicative term was included in the  
154 model to assess the interaction between ACWR and wellness measures. The odds ratios  
155 obtained from the GLMM model were converted to relative risks (RR) in order to interpret  
156 their magnitude (18). The smallest important increase in injury risk was a relative risk of 1.11,  
157 and the smallest important decrease in risk was 0.90 (17). An effect was deemed ‘*unclear*’ if  
158 the chance that the true value was beneficial was >25%, with odds of benefit relative to odds  
159 of harm (odds ratio) of <66. Otherwise, the effect was deemed clear, and was qualified with a  
160 probabilistic term using the following scale: <0.5%, *most unlikely*; 0.5-5%, *very unlikely*; 5-  
161 25%, *unlikely*; 25-75%, *possible*; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5%, *most likely*  
162 (16). The data is presented as means and 90% confidence intervals (CI) with injury likelihoods  
163 estimated at typically very low (-2SD), low (-1SD), mean, high (+1SD), and very high (+2SD)  
164 values of ACWR. These values were equivalent to ACWRs of 0.44, 0.67, 0.91, 1.14, and 1.38,  
165 respectively.

166

## 167 **RESULTS**

168 A total of 55 non-contact injuries were observed in this data set with 27 occurring in game  
169 time, 2 during strength-based conditioning, and 26 during field-based practice sessions. 42  
170 injuries were reported in the lower body affecting the ankle (15), knee (11), foot (5), posterior  
171 thigh (5), hip (5) and toe (1). The remaining 13 injuries were observed at the lumbar spine and  
172 lower back (7), shoulder (5) and elbow (1). A sprain or strain of the affected area encompassed  
173 67% of all injuries and the outstanding 33% comprised three or less diagnosed cases of bursitis,  
174 herniated disc, generalized pain, tendinitis, subluxation, plantar fasciitis, patellofemoral  
175 disorder, muscular imbalance, impingement, cyst, hyperextension or dysfunction.

### 176 *Injury risk and daily acute:chronic workloads*

177 The mean ACWR observed in this study was  $0.91 \pm 0.23$ . A characteristic rise in the probability  
178 for injury was observed with high and low ACWR (figure 1). Specifically, injury risks were

179 *very likely* higher when the ACWR was 2SD's above the mean (RR: 3.05, 90% CI: 1.14-8.16)  
180 and 2SD's below the mean (RR: 2.49, 90% CI: 1.11-5.58), when compared to the mean ACWR.

181

182 **INSERT FIGURE 1 ABOUT HERE**

183

184 *Injury risk and wellness*

185 Across the data set, typical mean wellness  $3.23 \pm 0.65$ , sleep  $3.32 \pm 0.83$ , energy  $3.34 \pm 0.78$ , and  
186 soreness  $3.05 \pm 0.88$  was reported. No clear effect on the likelihood of injury with "*better*"  
187 ( $>+1SD$ ) or "*worse*" ( $<-1SD$ ) reports of wellness, sleep, energy or soreness were observed  
188 (Figure 2).

189

190 **INSERT FIGURE 2 ABOUT HERE**

191

192 *Effect of ACWR on wellness*

193 Normality across the data set was not observed for any wellness variable and Spearman's  
194 correlations between the previous days EWMA ACWR with Sleep, Energy, Soreness and  
195 Overall wellness were performed. Significant ( $p < 0.05$ ), although *trivial* associations were  
196 observed when examining the change (Z score) in subjective ratings with "*worse*" scores in  
197 overall wellness ( $r = -0.06$  CI -0.10 to -0.02), muscle soreness ( $r = -0.07$ , CI -0.11 to -0.03),  
198 and energy ( $r = -0.05$  CI -0.09 to -0.01) observed when a higher ACWR was recorded the  
199 previous day.

200 *Wellness, acute:chronic workloads interactions and injury risk*

201 ACWR and wellness interactions highlight that individuals subjectively reporting "*better*"  
202 wellness when exposed to a high ( $+2SD$ ) ACWR had a *likely* higher risk of injury in the  
203 subsequent 3 days compared to those reporting "*normal*" (RR: 1.52, 90% CI: 0.91 to 2.54) or  
204 "*worse*" levels of wellness (RR: 2.36, 90% CI: 0.83 to 6.74) (figure 3). No clear interactions

205 were observed when examining subjective sleep ( $p = 0.74$ ) or energy ( $p = 0.88$ ) and ACWR  
206 associations with injury. However, a *likely* and *very likely* increase in the probability of injury  
207 was observed when high ACWR (+2SD) and “*better*” muscle soreness were collectively  
208 observed in comparison to “*normal*” (RR: 1.64, 90% CI: 1.10-2.47) and “*worse*” soreness  
209 levels (RR: 2.78, 90% CI: 1.21-6.38) (Figure 3).

210

211

**INSERT FIGURE 3 ABOUT HERE**

212

## 213 **DISCUSSION**

214 In this investigation of collegiate American Football, low and high ACWR’s increased the risk  
215 of injury. Our results highlight subsequently lower wellness, energy and increased muscle  
216 soreness following days that evoked high EWMA ACWR’s. Interestingly however the greatest  
217 risk of sustaining an injury (within 3 days) was observed when high ACWR and typically  
218 “*better*” perceived wellness, driven by perceived levels of soreness were collectively observed.  
219 To our knowledge, this study is the first to assess the relationship between an athlete’s ACWR  
220 and their state of wellness the following day, and the first to consider interactions between the  
221 ACWR and perceived wellness relative to the risk of injury.

222 Playerload<sup>TM</sup> was the chosen workload measure given it’s suitability for encompassing both  
223 indoor and outdoor training comprising acceleration, deceleration, sprint, and contact efforts  
224 (3, 34) and the frequency of these activities in college football (45, 46). Increased injury risks  
225 were observed at lower ACWR’s than those commonly reported, however the characteristic  
226 ‘U’ curve depicting a ‘sweet spot’ at moderate ACWR and injury risks 2.5 to 3 times greater  
227 with lower and higher ratios (13) was apparent. In practical terms, the change in workload  
228 associated with higher rates of injury at each end of the spectrum represented a relative increase  
229 or decrease in load of >40-50% which is consistent with ACWR-injury risks observed across  
230 a larger cohort of this group (37). High risk scenarios that may result in the high ACWR and  
231 lead to injury in college football such as “return to play” and unaccustomed game time have  
232 been proposed (37). However, despite the very likely higher injury risks associated with  
233 fluctuations of +/- 2SD from the mean workload in this cohort, the absolute risk did not exceed  
234 15%. Considering the negative effect of high workloads on an athletes self-reported wellness

235 (33, 40, 43), it was anticipated that lower subjective ratings of wellness observed concurrently  
236 with high and/or low EWMA ACWR's would amplify injury risks.

237 No clear associations between any subjective measure of wellness and the likelihood of injury  
238 were observed. However, wellness scores indicative of "*worse*" perceived wellness driven by  
239 energy and soreness were observed the day after a high ACWR. These associations appear to  
240 extend current research by highlighting the impact of workload spikes (generally) on an  
241 athlete's internal wellness. Given the deleterious effects that excessive workloads are known  
242 to have on an athlete's sleep (22), it was somewhat surprising that no associations with injury  
243 and EWMA ACWR workload spikes were observed. However, increased sleep efficiency has  
244 previously been observed during intense training in Rugby League players (39), suggesting  
245 that the impact of training on sleep may be positive in the absence of an overtrained or  
246 functionally overreached status. Nevertheless, given the apparent negative influence of a high  
247 ACWR on subjective rating of wellness and it was anticipated that the risk of injury would  
248 correspondingly be amplified with low wellness when considered as multiplicative variables.

249 It was therefore surprising to observe increased risks were predominantly associated with a  
250 high EWMA ACWR when athletes subjectively reported feeling "*better*" driven by perceived  
251 levels of soreness. As such, it should firstly be considered that the negative associations  
252 between EWMA ACWR and wellness we observed were *trivial* and the impact should be  
253 interpreted with caution. Furthermore, the association between soreness and high EWMA  
254 ACWR's observed in this investigation were likely affected by typically higher workloads on  
255 (35), and consistently increased muscle soreness following (11) game-day. The impact of  
256 games on subjective wellness has also been shown to perpetuate and deteriorate throughout the  
257 training week up to 4 days post game (11). Subjective reports of "*worse*" perceptions of  
258 wellness prior to training can reduce training outputs (14, 26) and more specifically "*worse*"  
259 muscle soreness has previously been related to a reduction in player effort (s-RPE) in college  
260 football players (15). It is possible that practitioners are responsive to negative wellness  
261 perceptions and may have intervened in this investigation to modulate training loads and/or  
262 players themselves may have self-regulated reductions in their training effort. Such actions  
263 may explain the low sensitivity that ACWR models have shown with injury (9, 29). Consistent  
264 with this theory, an athlete reporting "*better*" wellness and soreness may alternatively be pre-  
265 disposed to more frequent high intensity activities that are considering injury initiating events  
266 such as sprinting, accelerating and cutting (2, 24). Although we acknowledge that this remains

267 speculative, further research focusing on the relationship of daily fluctuations in subjective  
268 recovery responses and training outputs is warranted.

### 269 **Limitations**

270 The results of the current research do not suggest that adverse wellness increases the risk of  
271 injury. The pattern of injury was comparable to those reported in a recent longitudinal study  
272 (23) and previous accounts of the daily and seasonal GPS workload distribution in this team  
273 (32) are similar to that observed in other groups of NCAA division I footballers (44). However,  
274 a number of limitations must be recognised. Firstly, one should recognise that despite the  
275 similarities noted above, the current study is a report of a single season of injuries from a single  
276 team. As such, these outcomes may not be consistently reflected across college football when  
277 considering the varied training demands/schedules employed. Furthermore, whilst the number  
278 of injuries included in this investigation were considered sufficient to detect moderate-strong  
279 associations (1), the overall number was relatively low, and the associations observed were  
280 likely underpowered by examining interaction effects. Furthermore, in this and many similar  
281 investigations examining injury risks and workloads in team sports, only field-based workloads  
282 are considered. As such, although wellness may have been impacted on by workloads (such as  
283 resistance exercise) that were not measured in this investigation they were not included in the  
284 ACWR calculation. In addition, the variability in workload and injury risk that may be  
285 associated with positional demands and experience may have influenced our results (30) and  
286 academic, or other non-athletic stressors which can adversely affect wellness and amplify  
287 injury risks (28), were not recorded and could not be considered. Inadvertently more complex  
288 and confounding variables that influence fatigue, wellness, external and internal stress may  
289 thus have contributed to the risk of injury observed (31). The higher injury risk observed with  
290 high workloads and “*better*” wellness observed in this study may suggest that these  
291 confounding variables did not influence our results. However, the accuracy of the wellness  
292 reports used in this investigation should also be considered. Variations in wellness relative to  
293 game day have previously been observed from the 5 point Likert scale used in this investigation  
294 (11), the assessment thus appears sensitive to workloads inducing fatigue. At present the REST-  
295 Q is however the only wellness questionnaire that appears to have empirical evidence to show  
296 reliability relative to acute and chronic load variations (38).

297

298 **CONCLUSION**

299 In this investigation, athletic workload spikes resulted in reduced perceptions of wellness the  
300 following day, however the relationship was trivial. In contrast, the most at-risk group were  
301 athletes reporting “better” wellness driven by energy and muscle soreness. We suggest that  
302 this unexpected association may be a consequence of responsive practitioners applying  
303 interventions when negative perceptions of wellness are observed and, or effective self-  
304 modulation from players themselves. In this regard, it is also possible that high intensity  
305 activities which evoke an inherently greater risk of injury occur more frequently when athletes  
306 report “better” wellness. Future studies examining acute injury risks relative to wellness and  
307 high intensity activities are thus warranted.

308 **PRACTICAL APPLICATIONS**

309 Collectively, this study supports the use of simple non-invasive wellness measures to  
310 complement, injury monitoring and external load constructs within an effective athlete  
311 monitoring system for American Football. Specifically, we suggest practitioners 1) apply  
312 wellness monitoring within their daily practice to understand the affect and effect of training  
313 workloads; 2) where possible, utilise an EWMA ACWR and avoid daily fluctuations  $>1SD$  of  
314 a player’s average and; 3) closely monitor the workload and its composition relative to the  
315 planned activity, avoiding unplanned increases in workload even if “better” wellness is  
316 apparent.

317

318 **Acknowledgments:**

319 The authors would like to thank all players, staff and interns who assisted in this study.

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#### 452 **Figure descriptions:**

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454 Figure 1: Predicted probability of injury in college football players with deviations from the  
 455 mean EWMA ACWR.

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457 Figure 2: Predicted probability of injury in college football players with deviations from the  
 458 mean subjectively reported sleep, soreness, energy and overall wellness

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460 Figure 3: Interactive effect of a deviation from the mean EWMA ACWR when collectively  
461 considering a athletes state of perceived a) Overall Wellness, b) Soreness, c) Energy and d)  
462 Sleep Quality

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