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1 **The influence of perceptions of sleep on wellbeing in youth athletes**

2 Running head: Influence of sleep on wellbeing in youth athletes

3
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21 Abstract

22 To date, the majority of research considering wellbeing questionnaires has only considered the
23 training stress imposed on the athlete, without evaluating the questionnaire's relationship with a
24 measure of recovery (e.g. sleep). This study aimed to assess the influence of sleep duration (S_{duration}),
25 sleep quality (S_{quality}) and sleep index (S_{index} ; $S_{\text{duration}} \times S_{\text{quality}}$) on wellbeing in youth athletes, whilst
26 accounting for the known training stressors of training load and exposure to match play. Forty-eight
27 youth athletes (age 17.3 ± 0.5 years) completed a daily questionnaire including wellbeing ($DWB_{\text{no-}}$
28 sleep ; fatigue, muscle soreness, stress and mood) measures, Perceived Recovery Scale (PRS), the
29 previous day's training loads, S_{duration} and S_{quality} every day for 13 weeks. Linear mixed models
30 assessed the impact of S_{duration} , S_{quality} and S_{index} on $DWB_{\text{no-sleep}}$, its individual subscales, and PRS.
31 S_{duration} had a *small* effect on $DWB_{\text{no-sleep}}$ ($d=0.31; \pm 0.09$), fatigue ($d=0.42; \pm 0.11$) and PRS ($d=0.25;$
32 ± 0.09). S_{quality} had a *small* effect on $DWB_{\text{no-sleep}}$ ($d=0.47; \pm 0.08$), fatigue ($d=0.53; \pm 0.11$), stress
33 ($d=0.35; \pm 0.07$), mood ($d=0.41; \pm 0.09$) and PRS ($d=0.37; \pm 0.08$). S_{index} had a *small* effect on $DWB_{\text{no-}}$
34 sleep ($d=0.44; \pm 0.08$), fatigue ($d=0.55; \pm 0.11$), stress ($d=0.29; \pm 0.07$), mood ($d=0.37; \pm 0.09$) and PRS
35 ($d=0.36; \pm 0.09$). The results indicate that an athlete's perceptions of sleep are associated with
36 deviations in wellbeing measures and should be used as an input to the monitoring process rather than
37 as part of the outcome wellbeing score. The sleep index is suggested as a potential input as it provides
38 information on both the duration and quality of the sleep experienced.

39

40 Key words: Recovery, fatigue, youth, training, stress**41 Abstract word count:** 248**42 Total word count:** 3849

43

44 INTRODUCTION

45 In the last decade, there has been a large increase in research surrounding the sleep profiles of athletes
46 (16,22), and the health and performance consequences of sleep disturbances (9,39). Such research has
47 shown that athletes are liable to suffer reduced sleep quantity and quality (16,22,32), which can lead
48 to decrements in sporting performance (7,23), increased risk of illness (6) and deviations in wellbeing
49 measures (19,27). These findings have resulted in practitioners commonly including measures of
50 perceived sleep quality in daily wellbeing questionnaires aimed at monitoring their athletes (2,24,40).
51 Daily wellbeing questionnaires usually consist of items related to muscle soreness, appetite, sleep
52 quality, mood, stress and fatigue, and are tailored to the needs of the practitioners in question
53 (24,26,40). These subscales can be evaluated alone or grouped together to provide a total wellbeing
54 score, which can be compared to the previous day's training load to assess whether changes are
55 congruent with the training stress imposed on the athlete (25,36,37,40). However, given the influence
56 of sleep quality on athlete wellbeing (19,27,29), it is pertinent to question whether perceptions of
57 sleep should be an input, rather than an output measure of this athlete monitoring process.

58

59 Although the influence of training stress, measured by training load and exposure to match play, on
60 muscle soreness and fatigue/recovery based measures is well established (2,37,40), its relationship
61 with the overall wellbeing score has been questioned in the only study to consider a measure of
62 recovery alongside the training stress imposed (37). In this study, the authors found self-reported
63 sleep duration, as a measure of recovery, to have a *small* effect on a daily wellbeing scale (DWB; 23),
64 its fatigue subscale and the Perceived Recovery Status scale (PRS; 20), and a *moderate* effect on the
65 sleep quality DWB subscale in youth athletes (37). These findings indicate that poor recovery, rather
66 than increased training stress, may be a greater issue in youth athletes and provide scope for the use of
67 perceptions of sleep as predictors of changes in sport-specific wellbeing questionnaires.

68

69 It is unsurprising that there is currently little interest in self-reported sleep duration in the literature
70 given its validity against actigraphy measures has been questioned in the general population ($r = 0.45$;
71 19). However, recent studies have indicated that there is strong agreement between actigraphy based

72 measures and self-reported sleep duration in athletic populations ($r = 0.82-0.90$), particularly when
73 participants are asked to record their estimated time in bed rather than specific sleep duration ($r = 0.90$
74 *vs* $r = 0.85$; 3,16). Furthermore, the usefulness of this estimated time in bed method has previously
75 been shown with regards to illness as self-reported sleep duration, via the estimated time in bed
76 method, of less than seven hours has been related to a three times greater risk of the common cold (6).
77 Consequently, there is support for research considering the influence of self-reported sleep duration
78 on sport-specific athlete wellbeing measures.

79

80 Despite the promise of self-reported sleep duration as a measure of recovery in sport (37), studies
81 using students in education have shown the influence of perceptions of sleep quality on wellbeing
82 measures to be greater than sleep duration alone (27,29). Furthermore, pre-competition sleep quality
83 has been related to increased feelings of fatigue and tension, and reduced vigour on the morning of
84 competition as measured by the Brunel Mood Scale in marathon running participants (19). However,
85 perhaps because of its popularity as a subscale within sport specific wellbeing questionnaires, to the
86 authors' knowledge no study has considered the influence of sleep quality on athlete wellbeing
87 alongside training load and exposure to match play. Consequently, a study comparing the influence of
88 self-reported sleep quality and sleep duration on wellbeing alongside the training stressors of training
89 load and exposure to match play is merited. In addition to sleep duration and sleep quality alone, it
90 may be useful to consider the interaction between the two measures (termed 'sleep index' here) as a
91 predictor of changes in wellbeing. To date, no study has considered the influence of a sleep index on
92 wellbeing, but it is reasonable to expect that nine hours of "good" sleep will provide greater recovery
93 benefit than six hours of "good" sleep, as it involves two further full cycles of sleep (4). Therefore,
94 assessing the two measures in unison (i.e. a sleep index) could prove more predictive of outcome
95 measures than considering either sleep duration or sleep quality alone.

96

97 To date, there is a body of research suggesting that training load and exposure to match play, as
98 inputs, affect athlete wellbeing (25,37,40), however there is little research considering the use of
99 perceptions of sleep as mediators of the wellbeing response (37). As a result of this gap in the

100 literature, the aim of this study is to assess the influence of self-reported sleep duration, sleep quality
101 and sleep index on the wellbeing response, while controlling for the known training stressors of
102 training load and exposure to match play.

103

104 **Methods**

105 *Experimental Approach to the Problem*

106 This study explored the influence of self-reported sleep duration, sleep quality and sleep index on the
107 wellbeing response, while accounting for the known training stressors of training load and exposure to
108 match play. DWB_{no-sleep} (a four item DWB, created by removing the sleep quality measure), its
109 individual subscales (fatigue, muscle soreness, stress and mood) and PRS were used as wellbeing
110 measures. The study was conducted seven days per week over a 13-week period from February to
111 May. Participants completed a customised questionnaire to provide current details on DWB_{no-sleep},
112 PRS, and the previous day's self-reported sleep duration, sleep quality, training load and exposure to
113 match play. Training and match sessions continued as normal throughout the duration of the study.
114 Types of training sessions included: technical training, strength and conditioning training and
115 recovery sessions, all of which could be completed at school, for a club or in the participants personal
116 time. No restrictions were placed on participants' activities and the time these activities took place was
117 not recorded. Relationships between the independent and dependent variables were estimated in
118 separate models for each wellbeing scale and subscale.

119

120 *Subjects*

121 Forty-eight male and female youth athletes aged 16-18 years (age 17.3 ± 0.5 years, height $172.8 \pm$
122 18.3 cm, body mass 73.6 ± 12.8 kg) participated in this study. Participants were recruited from a local
123 independent school in the United Kingdom (UK), where they were members of the school's sport
124 scholarship programme. The sports; cricket ($n=5$), soccer ($n=10$), hockey ($n=10$), netball ($n=10$) and
125 rugby union ($n=13$) were represented by athletes competing at club/school ($n=29$), professional
126 academy ($n=6$), county/regional ($n=10$) and international ($n=3$) standard in their respective sports.

127 Ethics approval was granted by the University Ethics Committee and written informed consent was
128 provided by all participants and their parents prior to the study.

129

130 *Procedures*

131 The study was conducted seven days per week over a 13-week period from February to May.

132 Participants completed an online Google Docs (Google Forms, Google, CA, USA) questionnaire

133 before 11am every morning. On training days, the questionnaire was completed prior to the first

134 training session of the day. The form included a DWB related to sleep quality, fatigue, muscle

135 soreness, stress and mood (24), the PRS (21), self-reported sleep duration (in hours, using the

136 estimated time in bed method) and 24 hour training load recall. All participants had been familiarised

137 to the questionnaires prior to the study.

138

139 To assess the impact of perceptions of sleep on the wellbeing measures, the sleep quality subscale was

140 removed from DWB to create a four item $DWB_{no-sleep}$ scored out of 20. The sleep quality subscale was

141 analysed alone and multiplied by self-reported sleep duration to create the sleep index. For the 24-

142 hour training load recall, participants provided information with regards to the type, duration and

143 intensity of each session from the previous day. Type included technical training, strength and

144 conditioning training, personal gym and matches. Participants could complete multiple session types

145 on a single day, but every day where they participated in a match was used to calculate the additive

146 effect of exposure to match play on $DWB_{no-sleep}$ and PRS. The intensity of each session was rated

147 using the Borg category ratio-10 scale (8) choosing the respective descriptor, which was converted to

148 the associated rating of perceived exertion (RPE) number and multiplied by the session duration (in

149 minutes) to provide the session-RPE (s-RPE). The sum of all s-RPE's on a single day gave the daily

150 training load. The temporal robustness of the s-RPE method over 24 hours has previously been

151 confirmed (28,38), and the between-day reliability (typical error as a coefficient of variation) of PRS

152 has previously been evaluated in this population as 8.5% (36). The between-day reliability (typical

153 error as a coefficient of variation) of $DWB_{no-sleep}$ was calculated as 9.8% in this study.

154

155 *Statistical Analyses*

156 Data were analysed using SAS University Edition (SAS Institute, Cary, NC). A linear mixed model
157 (via Proc Mixed) was used to evaluate the influence of sleep duration, sleep quality and sleep index
158 on DWB_{no-sleep}, its subscales (fatigue, muscle soreness, stress and mood) and PRS, whilst controlling
159 for the effects of training load and match play exposure. Sport (referring to the athlete's sport), week
160 (referring to the week of the study), and day (referring to the day of the week) were added as fixed
161 factors. Training load, sleep duration, sleep quality and sleep index were mean centred by individual.
162 Each model contained training load as a time varying covariate and the dummy covariate match play
163 exposure, which was added on any day where a participant had competed in a match and accounted
164 for the additive influence of exposure to match play on wellbeing measures. Sleep duration, sleep
165 quality and sleep index were added as time varying covariates in separate models. Athlete*training
166 load*sleep (duration, quality or index dependent on the model) was added as an unstructured random
167 effect. This allowed the variation in the effect of training load and sleep on DWB_{no-sleep} and PRS
168 between individuals to be assessed. Three models were calculated for each scale/subscale analysis,
169 one using sleep duration, sleep quality and sleep index, resulting in the calculation of eighteen models
170 in total. Due to the difficulty in obtaining correlation coefficients from linear mixed models with
171 complicated random effects structures (30), the effect of the covariates was calculated by assessing a
172 two standard deviation (2 SD) difference in the covariate. This evaluates the difference between a
173 typically high and typically low training load or sleep characteristic and falls in line with previous
174 research (13,25).

175

176 Following the recent criticisms of both p-values (43) and magnitude based inferences (31), results
177 were analysed for practical significance by observing the effect sizes (ES) and their 90% confidence
178 intervals. A full breakdown of null-hypothesis significance testing and magnitude based inferences for
179 the covariates in each model is provided as supplementary content (Table, supplemental digital
180 content 1-3). The threshold for a change to be considered practically important (the smallest
181 worthwhile change) was set as 0.2 x observed between participant SD, based on Cohen's *d* ES

182 principle. Thresholds for ES were set as: 0.2 *small*; 0.6 *moderate*; 1.2 *large*; 2.0 *very large*. The ES of
183 random effects were doubled to fit the same ES criteria, as opposed to halving the thresholds (12).

184

185 **Results**

186 2727 data points were collected and analysed for this study at a median response rate of 54/91
187 completions (range 14-91). Overall, 2181 training sessions, 292 matches and 991 rest days were
188 included. The mean daily training load was 250 ± 317 AU and a 2 SD change was equivalent to $556 \pm$
189 208 AU. The mean sleep duration was 7.7 ± 1.5 hours, the mean sleep quality score was 4 ± 1 AU and
190 the mean sleep index was 29 ± 9 AU. A 2 SD change was equivalent to 2.6 ± 1.3 hours, 3 ± 1 AU and
191 14 ± 6 AU for sleep duration, sleep quality and sleep index respectively.

192

193 Figure 1 provides a graphical representation of the effect of self-reported sleep duration, sleep quality
194 and sleep index on $DWB_{no-sleep}$, its individual subscales and PRS. With the exception of the muscle
195 soreness subscale and the influence of sleep duration on stress, the relationships between perceptions
196 of sleep and wellbeing measures were *small*. Sleep quality and sleep index showed stronger
197 relationships with all wellbeing measures than sleep duration. Table 1 shows the between participant
198 variation in the impact of the sleep characteristics on the wellbeing measures. Sleep quality showed
199 the smallest between participant variation of the three sleep characteristics for all wellbeing measures
200 except $DWB_{no-sleep}$, where sleep index was smallest.

201

202 *INSERT FIGURE 1 AND TABLE 1 AROUND HERE*

203

204 Table 2 provides standardised effect sizes for the influence of training load and exposure to match
205 play on $DWB_{no-sleep}$, its individual subscales and PRS for the models containing sleep duration, sleep
206 quality and sleep index. The random effects of training load and exposure to match play for DWB_{no-}
207 $sleep$ (*trivial to small* effects; $d=0.18-0.20$), its individual subscales (*small to moderate* effects
208 dependent on the subscale; $d=0.22-0.85$) or PRS (*small to moderate* effects; $d=0.55-0.62$) showed no
209 difference between sleep duration, sleep quality and sleep index models.

210

211

INSERT TABLE 2 AROUND HERE

212

213 Discussion

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DWB_{no-sleep}

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The aim of this study was to assess the influence of self-reported sleep duration, sleep quality and sleep index on $DWB_{no-sleep}$, its individual subscales and the PRS in youth athletes, while controlling for the known effects of training load and exposure to match play. Our results indicate sleep duration, sleep quality and sleep index all had a *small* effect on $DWB_{no-sleep}$, fatigue and PRS. Sleep quality and sleep index also exhibited a *small* influence on stress and mood. On all occasions, the influence of sleep quality and sleep index was greater than sleep duration (Figure 1). In all models, training load and match play exposure had a *small* effect on muscle soreness and PRS. All other effects were *trivial* or were not considered practically significant.

Our results suggest sleep duration, sleep quality and sleep index have a *small* effect on $DWB_{no-sleep}$ in youth athletes. The *small* influence of sleep duration on $DWB_{no-sleep}$ supports previous research showing the same association with DWB (37). However, upon removal of the sleep quality measure from DWB, the influence of sleep duration on $DWB_{no-sleep}$ was reduced. Although little correlation has been reported between sleep duration and sleep quality in non-athletic adolescents (29), research in youth athletes has indicated a *moderate* relationship between self-reported sleep duration and the sleep quality subscale used in this study (37). It is therefore possible that this association between sleep duration and sleep quality, coupled with the relationship between sleep quality and other wellbeing subscales shown in our study may have skewed the DWB score in line with the sleep durations experienced, resulting in an inaccurately strong relationship between sleep duration and DWB in previous studies (36,37). Regardless, our study suggests that both sleep quality and sleep index measures are better predictors of changes in the overall wellbeing score than sleep duration and provides support for their use as an input to, rather than an output of, the monitoring process.

238 *PRS and fatigue*

239 We observed that sleep quality and sleep index have a greater influence on PRS and the fatigue
240 subscale than sleep duration, however all three sleep characteristics had the same *small* effect on both
241 wellbeing measures. The influence of sleep quality on fatigue is remarkably similar in size to the
242 *small* correlation observed in marathon participants prior to competitive performance (19), and the
243 relationship between sleep duration and these fatigue measures is consistent with previous studies
244 using both actigraphy (32) and self-report measures (27). However, the between participant variation
245 in the effect of sleep quality on PRS and fatigue was much lower than that of sleep duration and sleep
246 index (Table 1). This difference could be explained by the variation in athletes' perceptions of good
247 sleep quality and its influence on recovery (18). For some athletes, good sleep quality may refer to
248 uninterrupted sleep, regardless of the duration, in which case the inclusion of the sleep duration term
249 in the sleep index could result in multiplicative error (i.e. if a participant reports sleep duration that is
250 one hour wrong, the difference will be multiplied by the sleep quality score to magnify this error). For
251 others, however, sleep duration may play a role in their perceptions of sleep quality, potentially
252 resulting in smaller differences between participants. These differences in the importance of sleep
253 duration to perceptions of recovery and fatigue could explain the discrepancy between sleep quality
254 and sleep index at an individual level. Furthermore, the discrepancies indicate that, for the purposes of
255 measuring an athlete's perceptions of fatigue/recovery, sleep quality is the most consistent and
256 therefore potentially most useful measure of the sleep characteristics considered in this study.

257

258 *Mood and stress*

259 Figure 1 depicts the *small* influence of sleep quality and sleep index on mood and stress, which was
260 more certain than the *small* relationship observed between mood and sleep duration, and greater than
261 the *trivial* relationship reported between stress and sleep duration. Sleep duration and sleep quality
262 have previously been related to changes in mood in longer questionnaires (19,27), but in a previous
263 study considering the influence of sleep duration on mood and stress in a short sport-specific
264 questionnaire, no relationship was observed (37). Sleep quality can have a highly individual meaning,
265 but it may include number of sleep disturbances, sleep onset latency, sleep efficiency or total sleep

266 duration dependent on the individual (18), each of which could reduce the restorative capacity of
267 sleep by limiting rapid eye movement or non-rapid eye movement sleep durations (42). Given stress is
268 normally considered along a stress-recovery continuum (14), it is logical that if recovery (in this case
269 measured by perceptions of sleep) is reduced, it would result in greater feelings of stress. Both sleep
270 quality and sleep index showed *small* between participant variation in their impact on mood and
271 stress. This contrasts with the widely varying responses they showed in their effect on perceptions of
272 recovery and suggests that when assessing mood and stress, the two measures could be used
273 interchangeably with consistent results.

274

275 *Muscle soreness*

276 None of the sleep measures had an influence on muscle soreness, but training load and match stress
277 both had a *small* effect on the measure. This confirms previous findings (37) and it is logical that the
278 more intense the stimulus, as measured by training load and exposure to match play, the more severe
279 the muscle damage and remodelling experienced. It is possible that sleep was not related to muscle
280 soreness as delayed onset muscle soreness can increase in intensity for up to 72 hours as part of the
281 recovery process (5).

282

283 *Limitations*

284 Despite our data providing useful additions to the literature, particularly with regards to the removal
285 of a sleep-based measure from current wellbeing questionnaires, the validity of this finding cannot be
286 fully confirmed until further research is completed. Self-report wellbeing measures are cost effective,
287 time efficient and easy to analyse (34); however, whilst their validity relative to objective measures
288 has been confirmed in longer questionnaires (e.g. the recovery-stress questionnaire for athletes (REST-
289 Q; 15), the validity of shorter sport specific questionnaires, like the one used here, is still uncertain
290 (35). In order to fully evaluate the validity of subjective wellbeing measures, Saw and colleagues (33)
291 have produced a 13 point checklist of information to include. Whilst our study provides appropriate
292 information for the majority of these points, it does not fully answer points 6, 7 and 12 relating to the
293 validity, reference values and smallest meaningful change of the questionnaire. The aim of this study

294 was to establish whether subjective sleep measures influenced the other subscales of commonly used
295 wellbeing questionnaires. Now that this has been observed, there is a rationale for further research to
296 consider reference values and meaningful changes of the questionnaire in relation to the true outcome
297 measures of performance, injury and illness. However, it is acknowledged that this task could prove
298 difficult as the use of self-report measures alone to understand match performance or within injury
299 monitoring can be criticised because they provide little understanding of the external work
300 undertaken. Specific external workload measures (e.g. high speed running via GPS measurements)
301 have shown good accuracy within this domain via acute:chronic workload injury prevention models
302 (11). However, whereas there is a clear break point for injury monitoring (i.e. medical attention or
303 time loss injuries (10)), there is no definitive point where match performance may improve or decline
304 in response to changes in a wellbeing questionnaire. Consequently, it could be that perceptions of
305 previous training or sleep activities could be more important than objective measures as this
306 perception of events may have the greatest impact on an athlete's ability to achieve their optimal flow
307 state for performance (1). Additionally, although our study has considered the influence of sleep and
308 training load on wellbeing measures, it is unable to account for the indirect relationship these
309 measures may have on each other. Intensive training in the evening, for example, has been shown to
310 impact upon sleep quality (41), which our study has shown can considerably influence wellbeing
311 measures. Similarly, when training is scheduled in the early morning, this has been shown to reduce
312 sleep duration, which can influence wellbeing (32). It is therefore essential that practitioners consider
313 a holistic approach to monitoring and understand that there could be direct and indirect relationships
314 between sleep, training load, exposure to match play and wellbeing measures. Finally, it should be
315 noted that the response rate for this study (median 54/91 completions, range 14-91) may have
316 impacted upon the findings observed. However, it could be argued that this increases the ecological
317 validity of the results as it is extremely difficult in practice to obtain 100% compliance from athletes
318 in monitoring programmes.

319

320 PRACTICAL APPLICATIONS

321 In conclusion, our results provide support for the use of sleep quality and sleep index as inputs to the
322 monitoring process, alongside training load and exposure to match play, rather than as outputs. The
323 sleep quality measure showed the largest and most consistent relationship with $DWB_{no-sleep}$, fatigue,
324 mood, stress and PRS, but the difference between sleep quality and sleep index was negligible, except
325 for in the individual responses to the recovery based measures of PRS and fatigue. This is important
326 due to the raw change required to elicit the statistical change observed. On a 1-5 scale, a 2 SD
327 difference in sleep quality was equivalent to a change of 3 ± 1 units, whereas for sleep index it was 14
328 ± 6 AU. A change of 3 units in the sleep quality subscale is a large proportion of the overall score
329 suggesting it may be unlikely to happen, however a change of 14 units in the sleep index scale is more
330 likely. Based on this difference and its incorporation of both sleep duration and quality measures into
331 one score, the authors would recommend the use of sleep index as a measure of perceptions of sleep
332 within monitoring models. However, future studies may wish to consider larger sleep quality scales
333 (i.e. 0-100 rather than 1-5), which may provide greater sensitivity to deviations in wellbeing, as this
334 measure maintains considerable promise as a predictor of changes in wellbeing.

335

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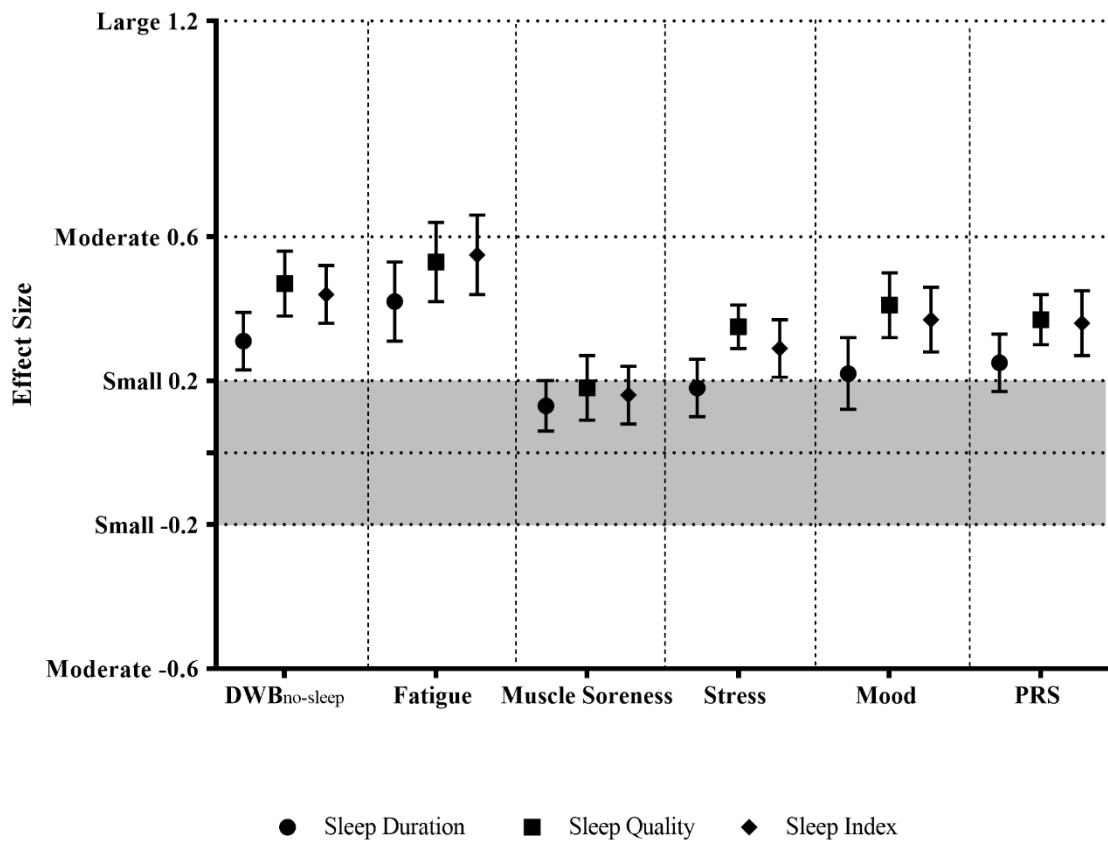
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447 **Figure 1:** Graphical depiction of influence of sleep duration, sleep quality and sleep index on DWB_{no-}
 448 $_{sleep}$, its individual subscales (fatigue, muscle soreness, stress and mood) and PRS. Effect sizes (ES)
 449 are provided for a 2 standard deviation difference in the covariate and are presented $ES \pm 90\%$
 450 confidence intervals. Shaded area represents smallest worthwhile change.



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Table 1: Between participant variation in the impact of self-reported sleep duration, sleep quality and sleep index on $DWB_{no-sleep}$, its individual subscales (fatigue, muscle soreness, stress and mood) and PRS. Data are effect size (90% confidence interval lower bound, 90% confidence interval upper bound). Qualitative descriptions of the effect size are provided in italics.

	Sleep duration	Sleep quality	Sleep index
$DWB_{no-sleep}$	0.46 (0.28, 0.92) <i>Small</i>	0.45 (0.27, 0.91) <i>Small</i>	0.39 (0.23, 0.83) <i>Small</i>
Fatigue	1.56 (1.01, 2.81) <i>Large</i>	1.19 (0.73, 2.31) <i>Moderate</i>	1.43 (0.92, 2.60) <i>Large</i>
Muscle Soreness	0.33 (0.17, 0.98) <i>Small</i>	0.69 (0.40, 1.49) <i>Moderate</i>	0.49 (0.28, 1.16) <i>Small</i>
Stress	0.42 (0.22, 1.14) <i>Small</i>	0.30 (0.16, 0.86) <i>Small</i>	0.39 (0.20, 1.13) <i>Small</i>
Mood	0.68 (0.42, 1.37) <i>Moderate</i>	0.42 (0.23, 1.10) <i>Small</i>	0.53 (0.31, 1.16) <i>Small</i>
PRS	0.64 (0.38, 1.35) <i>Moderate</i>	0.33 (0.16, 1.28) <i>Small</i>	0.65 (0.35, 1.70) <i>Moderate</i>

Table 2: Influence of training load (TL) and exposure to match play (EMP) on $DWB_{no-sleep}$, its individual subscales (fatigue, muscle soreness, stress and mood) and PRS. Sleep duration, sleep quality and sleep index headers denote the third covariate in the model (effect sizes for these covariates are shown in Figure 1). Effect sizes (ES) are ES; \pm 90% confidence interval. Qualitative description of effect size is given in italics.

	Sleep Duration		Sleep Quality		Sleep Index	
	TL	EMP	TL	EMP	TL	EMP
$DWB_{no-sleep}$	-0.19; \pm 0.07	-0.12; \pm 0.06	-0.18; \pm 0.07	-0.13; \pm 0.07	-0.19; \pm 0.06	-0.12; \pm 0.08
	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>
Fatigue	-0.15; \pm 0.08	-0.07; \pm 0.08	-0.16; \pm 0.08	-0.10; \pm 0.08	-0.16; \pm 0.08	-0.08; \pm 0.08
	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>
Muscle Soreness	-0.43; \pm 0.09	-0.26; \pm 0.09	-0.44; \pm 0.10	-0.26; \pm 0.09	-0.44; \pm 0.10	-0.26; \pm 0.09
	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>
Stress	0.02; \pm 0.07	0.01; \pm 0.08	0.02; \pm 0.07	0.00; \pm 0.08	0.02; \pm 0.07	0.01; \pm 0.08
	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>
Mood	0.02; \pm 0.06	-0.02; \pm 0.10	0.00; \pm 0.06	-0.02; \pm 0.10	0.00; \pm 0.06	-0.02; \pm 0.10
	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>	<i>Trivial</i>
PRS	-0.37; \pm 0.08	-0.25; \pm 0.08	-0.37; \pm 0.09	-0.26; \pm 0.08	-0.37; \pm 0.09	-0.25; \pm 0.08
	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>	<i>Small</i>

N.B: TL = Training load; EMP = Exposure to match play

Supplemental Digital Content 1: Table showing influence of covariates on wellbeing measures for model including sleep duration as time varying covariate. Standardised effect sizes (ES) are provided for a 2 standard deviation change in the time varying covariates (sleep duration and training load) and for the presence of the dummy covariate (exposure to match play; EMP). They are presented ES; \pm 90% confidence intervals for magnitude based inferences (MBI) and ES; \pm 95% confidence intervals for null hypothesis significance testing (NHST). A qualitative description of effect size is given in italics. For MBIs, likelihood of effect size is denoted by asterixes: * *possibly*; ** *likely*; *** *very likely*; **** *most likely*. For NHST, significance is denoted by superscripted letters: ^a significant at $p < 0.05$; ^b significant at $p < 0.01$; ^c significant at $p < 0.001$.

	MBI ES	MBI Descriptor	NHST ES	NHST ES Descriptor	NHST P- value
DWB_{no-sleep}					
Sleep duration	0.31; \pm 0.08	<i>Small</i> ***	0.31; \pm 0.10	<i>Small</i>	P<0.0001 ^c
Training Load	-0.19; \pm 0.07	<i>Trivial</i> *	-0.19; \pm 0.07	<i>Trivial</i>	P<0.0001 ^c
EMP	-0.12; \pm 0.08	<i>Trivial</i> **	-0.12; \pm 0.09	<i>Trivial</i>	P=0.01 ^a
Fatigue					
Sleep duration	0.42; \pm 0.11	<i>Small</i> ****	0.42; \pm 0.14	<i>Small</i>	P<0.0001 ^c
Training Load	-0.15; \pm 0.08	<i>Trivial</i> **	-0.15; \pm 0.09	<i>Trivial</i>	P=0.002 ^b
EMP	-0.07; \pm 0.08	<i>Trivial</i> ****	-0.07; \pm 0.10	<i>Trivial</i>	P=0.16
Muscle Soreness					
Sleep duration	0.13; \pm 0.07	<i>Trivial</i> **	0.13; \pm 0.09	<i>Trivial</i>	P=0.007 ^b
Training Load	-0.43; \pm 0.10	<i>Small</i> ****	-0.43; \pm 0.12	<i>Small</i>	P<0.0001 ^c
EMP	-0.26; \pm 0.09	<i>Small</i> **	-0.26; \pm 0.11	<i>Small</i>	P<0.0001 ^c
Stress					
Sleep duration	0.18; \pm 0.08	<i>Trivial</i> *	0.18; \pm 0.09	<i>Small</i>	P<0.001 ^b
Training Load	0.02; \pm 0.07	<i>Trivial</i> ****	0.02; \pm 0.08	<i>Trivial</i>	P=0.58
EMP	0.01; \pm 0.08	<i>Trivial</i> ****	0.01; \pm 0.11	<i>Trivial</i>	P=0.84
Mood					
Sleep duration	0.22; \pm 0.10	<i>Small</i> *	0.22; \pm 0.12	<i>Small</i>	P<0.001 ^b
Training Load	0.02; \pm 0.06	<i>Trivial</i> ****	0.02; \pm 0.07	<i>Trivial</i>	P=0.64
EMP	-0.02; \pm 0.10	<i>Trivial</i> ****	-0.02; \pm 0.12	<i>Trivial</i>	P=0.77
PRS					
Sleep duration	0.25; \pm 0.08	<i>Small</i> **	0.25; \pm 0.10	<i>Small</i>	P<0.0001 ^c
Training Load	-0.37; \pm 0.09	<i>Small</i> ****	-0.37; \pm 0.10	<i>Small</i>	P<0.0001 ^c
EMP	-0.25; \pm 0.09	<i>Small</i> **	-0.25; \pm 0.10	<i>Small</i>	P<0.0001 ^c

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Supplemental Digital Content 2: Table showing influence of covariates on wellbeing measures for model including sleep quality as time varying covariate. Standardised effect sizes (ES) are provided for a 2 standard deviation change in the time varying covariates (sleep quality and training load) and for the presence of the dummy covariate (exposure to match play; EMP). They are presented ES; \pm 90% confidence intervals for magnitude based inferences (MBI) and ES; \pm 95% confidence intervals for null hypothesis significance testing (NHST). A qualitative description of effect size is given in italics. For MBIs, likelihood of effect size is denoted by asterixes: * *possibly*; ** *likely*; *** *very likely*; **** *most likely*. For NHST, significance is denoted by superscripted letters: ^a significant at $p < 0.05$; ^b significant at $p < 0.01$; ^c significant at $p < 0.001$.

	MBI ES	MBI Descriptor	NHST ES	NHST ES Descriptor	NHST P- value
DWB_{no-sleep}					
Sleep quality	0.47; \pm 0.09	<i>Small****</i>	0.47; \pm 0.10	<i>Small</i>	P<0.0001 ^c
Training Load	-0.18; \pm 0.07	<i>Trivial*</i>	-0.18; \pm 0.08	<i>Trivial</i>	P<0.0001 ^c
EMP	-0.13; \pm 0.07	<i>Trivial**</i>	-0.13; \pm 0.09	<i>Trivial</i>	P=0.003 ^b
Fatigue					
Sleep quality	0.53; \pm 0.11	<i>Small****</i>	0.53; \pm 0.13	<i>Small</i>	P<0.0001 ^c
Training Load	-0.16; \pm 0.08	<i>Trivial**</i>	-0.16; \pm 0.10	<i>Trivial</i>	P=0.003 ^b
EMP	-0.10; \pm 0.08	<i>Trivial***</i>	-0.10; \pm 0.10	<i>Trivial</i>	P=0.04 ^a
Muscle Soreness					
Sleep quality	0.18; \pm 0.09	<i>Trivial*</i>	0.18; \pm 0.11	<i>Trivial</i>	P=0.002 ^b
Training Load	-0.44; \pm 0.10	<i>Small****</i>	-0.44; \pm 0.12	<i>Small</i>	P<0.0001 ^c
EMP	-0.26; \pm 0.10	<i>Small**</i>	-0.26; \pm 0.11	<i>Small</i>	P<0.0001 ^c
Stress					
Sleep quality	0.35; \pm 0.06	<i>Small****</i>	0.35; \pm 0.08	<i>Small</i>	P<0.0001 ^c
Training Load	0.02; \pm 0.07	<i>Trivial****</i>	0.02; \pm 0.09	<i>Trivial</i>	P=0.64
EMP	0.00; \pm 0.08	<i>Trivial****</i>	0.00; \pm 0.10	<i>Trivial</i>	P=0.95
Mood					
Sleep quality	0.41; \pm 0.09	<i>Small****</i>	0.41; \pm 0.10	<i>Small</i>	P<0.0001 ^c
Training Load	0.00; \pm 0.06	<i>Trivial****</i>	0.00; \pm 0.07	<i>Trivial</i>	P=0.94
EMP	-0.02; \pm 0.10	<i>Trivial****</i>	-0.02; \pm 0.10	<i>Trivial</i>	P=0.75
PRS					
Sleep quality	0.37; \pm 0.07	<i>Small****</i>	0.37; \pm 0.09	<i>Small</i>	P<0.0001 ^c
Training Load	-0.37; \pm 0.09	<i>Small****</i>	-0.37; \pm 0.10	<i>Small</i>	P<0.0001 ^c
EMP	-0.26; \pm 0.08	<i>Small**</i>	-0.26; \pm 0.10	<i>Small</i>	P<0.0001 ^c

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Supplemental Digital Content 3: Table showing influence of covariates on wellbeing measures for model including sleep index as time varying covariate. Standardised effect sizes (ES) are provided for a 2 standard deviation change in the time varying covariates (sleep index and training load) and for the presence of the dummy covariate (exposure to match play; EMP). They are presented ES; \pm 90% confidence intervals for magnitude based inferences (MBI) and ES; \pm 95% confidence intervals for null hypothesis significance testing (NHST). A qualitative description of effect size is given in italics. For MBIs, likelihood of effect size is denoted by asterixes: * *possibly*; ** *likely*; *** *very likely*; **** *most likely*. For NHST, significance is denoted by superscripted letters: ^a significant at $p < 0.05$; ^b significant at $p < 0.01$; ^c significant at $p < 0.001$.

	MBI ES	MBI Descriptor	NHST ES	NHST ES Descriptor	NHST P- value
DWB_{no-sleep}					
Sleep index	0.44; \pm 0.08	<i>Small</i> ****	0.44; \pm 0.09	<i>Small</i>	P<0.0001 ^c
Training Load	-0.19; \pm 0.07	<i>Trivial</i> *	-0.19; \pm 0.08	<i>Trivial</i>	P<0.0001 ^c
EMP	-0.12; \pm 0.08	<i>Trivial</i> ***	-0.12; \pm 0.09	<i>Trivial</i>	P=0.009 ^b
Fatigue					
Sleep index	0.55; \pm 0.11	<i>Small</i> ****	0.55; \pm 0.13	<i>Small</i>	P<0.0001 ^c
Training Load	-0.16; \pm 0.08	<i>Trivial</i> **	-0.16; \pm 0.09	<i>Trivial</i>	P=0.002 ^b
EMP	-0.08; \pm 0.08	<i>Trivial</i> ****	-0.08; \pm 0.10	<i>Trivial</i>	P=0.09
Muscle Soreness					
Sleep index	0.16; \pm 0.08	<i>Trivial</i> **	0.16; \pm 0.10	<i>Trivial</i>	P=0.002 ^b
Training Load	-0.44; \pm 0.10	<i>Small</i> ****	-0.44; \pm 0.12	<i>Small</i>	P<0.0001 ^c
EMP	-0.26; \pm 0.09	<i>Small</i> **	-0.26; \pm 0.11	<i>Small</i>	P<0.0001 ^c
Stress					
Sleep index	0.29; \pm 0.08	<i>Small</i> ***	0.29; \pm 0.09	<i>Small</i>	P<0.0001 ^c
Training Load	0.02; \pm 0.07	<i>Trivial</i> ****	0.02; \pm 0.08	<i>Trivial</i>	P=0.66
EMP	0.01; \pm 0.08	<i>Trivial</i> ****	0.01; \pm 0.10	<i>Trivial</i>	P=0.84
Mood					
Sleep index	0.37; \pm 0.09	<i>Small</i> ****	0.37; \pm 0.11	<i>Small</i>	P<0.0001 ^c
Training Load	0.00; \pm 0.06	<i>Trivial</i> ****	0.00; \pm 0.07	<i>Trivial</i>	P=0.90
EMP	-0.02; \pm 0.10	<i>Trivial</i> ****	-0.02; \pm 0.12	<i>Trivial</i>	P=0.78
PRS					
Sleep index	0.36; \pm 0.09	<i>Small</i> ****	0.36; \pm 0.10	<i>Small</i>	P<0.0001 ^c
Training Load	-0.37; \pm 0.09	<i>Small</i> ****	-0.37; \pm 0.10	<i>Small</i>	P<0.0001 ^c
EMP	-0.25; \pm 0.08	<i>Small</i> **	-0.25; \pm 0.10	<i>Small</i>	P<0.0001 ^c