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1 **Title**

2 Understanding sleep disturbance in athletes prior to important competitions.

3

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24

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**Title**

Understanding sleep disturbance in athletes prior to important competitions.

**Running Header**

Athletes sleep behaviours prior to competition

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Sleep complaints, sleep strategies.

28 **Abstract**

29 Objectives: Anecdotally many athletes report worse sleep in the nights prior to important  
30 competitions. Despite sleep being acknowledged as an important factor for optimal athletic  
31 performance and overall health, little is understood about athlete sleep around competition.  
32 The aims of this study were to identify sleep complaints of athletes prior to competitions and  
33 determine whether complaints were confined to competition periods. Design: Cross-  
34 sectional study. Methods: A sample of 283 elite Australian athletes (129 male, 157 female,  
35 age  $24 \pm 5$  yr) completed two questionnaires; Competitive Sport and Sleep questionnaire and  
36 the Pittsburgh Sleep Quality Index. Results: 64.0% of athletes indicated worse sleep on at  
37 least one occasion in the nights prior to an important competition over the past 12 months.  
38 The main sleep problem specified by athletes was problems falling asleep (82.1%) with the  
39 main reasons responsible for poor sleep indicated as thoughts about the competition (83.5%)  
40 and nervousness (43.8%). Overall 59.1% of team sport athletes reported having no strategy  
41 to overcome poor sleep compared with individual athletes (32.7%,  $p = 0.002$ ) who utilised  
42 relaxation and reading as strategies. Individual sport athletes had increased likelihood of  
43 poor sleep as they aged. The poor sleep reported by athletes prior to competition was  
44 situational rather than a global sleep problem. Conclusion: Poor sleep is common prior to  
45 major competitions in Australian athletes, yet most athletes are unaware of strategies to  
46 overcome the poor sleep experienced. It is essential coaches and scientists monitor and  
47 educate both individual and team sport athletes to facilitate sleep prior to important  
48 competitions.

49

50 **Introduction**

51           Within elite sport, success is underpinned by optimal preparation<sup>1</sup> and, equally  
52 important, adequate recovery between training and during competition<sup>2, 3</sup>. Sleep has been  
53 recognised as an essential component for athlete preparation and is suggested to be the  
54 single best recovery strategy available to an athlete<sup>4, 5</sup>. Despite the importance of sleep for  
55 athletic performance, data on elite athletes is limited<sup>5</sup>. Anecdotal reports suggest athletes  
56 often sleep worse around competition periods, particularly the night(s) prior to an important  
57 competition<sup>6, 7</sup>. With reduced sleep shown to negatively influence performance this  
58 reduction may become problematic<sup>8, 9</sup>. Sleep deprivation studies in athletes has found  
59 decreased anaerobic performances through decreased mean and total sprint time in team  
60 sport athletes after 30h of sleep deprivation<sup>10</sup> and decreased aerobic performance following  
61 24 h of reduced sleep<sup>11</sup>. Whilst it may be seldom that athletes experience total sleep  
62 deprivation prior to competition, acute partial sleep deprivation may exist. One night of poor  
63 sleep in athletes is associated with reduced reaction times<sup>12</sup>, reduced anaerobic performance  
64 the following afternoon in football players<sup>13</sup> and declines in cognitive processes such as  
65 visual tracking, focus, determination and mood<sup>14, 15</sup>. As many sports rely on fine motor  
66 movements and the ability to make fast accurate decisions, reduced sleep in athletes is a  
67 genuine concern<sup>16</sup>.

68           As it is possible that sleep quantity and quality may influence performance<sup>17</sup>, there  
69 is a growing need to understand sleep patterns in elite athletes. To date, relatively few  
70 studies exist which provide this information<sup>3, 7, 18-20</sup>. In a survey of 632 German athletes  
71 prior to competition, 65.8% acknowledged worse sleep than normal at least once before a  
72 competition, indicating their main issue to be “problems falling asleep” (79.9%), due to  
73 “thoughts about the competition/game” (77%) and because of this “increased daytimes  
74 sleepiness” with athletes indicating “no special strategy” to enhance sleep<sup>6</sup>. These findings  
75 provide valuable information on sleep habits of the elite athlete and provide a stimulus for  
76 further investigation. Furthermore, if elite athletes do present as “poor” sleepers it is

77 important to differentiate poor competition sleep from chronic sleep issues if coaches,  
78 athletes and sports scientists hope to use this knowledge to enhance future performance.

79 The purpose of this study was to document the occurrence of sleep disturbances in  
80 athletes prior to important competitions and/or games. If sleep disturbances were indicated  
81 by athletes, we aimed to examine the particular problems, reasons and perceived  
82 consequences associated with the sleep disturbance. In addition from the information  
83 obtained we sought to determine whether a particular group of athletes had an increased  
84 likelihood of sleep disturbance. This study additionally aimed to provide a comprehensive  
85 analysis of whether individual versus team sport athlete sleep habits differ. Finally, a novel  
86 aspect of the study was to establish whether sleep disturbances are a general complaint  
87 present on a day-to-day basis in athletes or whether it is merely situational.

88

## 89 **Methods**

90 A sample of 283 elite Australian athletes (mean  $\pm$  SD; age:  $24 \pm 5$  y, age range: 16-  
91 47 y) volunteered to participate in the study from a variety of Australian sports (Table 1 and  
92 2). Athletes were recruited from the Australian Institute of Sport, Australian Winter Olympic  
93 team, Australian Paralympic team and National Sporting Organisations through personal  
94 contact with researchers or through coaching and/or support staff. All athletes were at an  
95 international level or were members of professional teams. The athletes sampled had  
96 competed in their sport for a mean of  $11 \pm 6$  y, trained on average  $16:42 \pm 6:42$  hr per week,  
97 slept on average  $7:42 \pm 0:54$  hr per night and had competed in  $14 \pm 13$  important  
98 competitions or games in the past twelve months (Table 2). Ethical approval was obtained  
99 from \_\_\_\_\_ and the \_\_\_\_\_ ethics committees prior to data  
100 collection.

101 In the period prior to (1 month) and following (7 months) the 2012 Olympic games,  
102 participants were asked to complete two questionnaires regarding their sleep (Competitive  
103 Sports and Sleep Questionnaire<sup>6</sup> and the Pittsburgh Sleep Quality Index<sup>21</sup> ) either online  
104 (Survey Monkey<sup>®</sup>) or through hard copy.

105           The Competitive Sports and Sleep questionnaire<sup>10</sup>, previously described by Erlacher  
106 and colleagues<sup>6</sup>, is a sport specific questionnaire used to assess sleep habits and dreams of  
107 athletes prior to important competitions and games. The questionnaire is divided into three  
108 main sections. The first section is used to obtain demographic data and information about the  
109 athlete's chosen sport. This information was used to categorise athletes into male and  
110 female, team sport or individual sport and in season or out of season at the time of answering  
111 the questionnaire, for statistical purposes. The subsequent section aims to obtain information  
112 on athlete sleep habits prior to important competitions or games. If an athlete answered  
113 "yes" to having poor sleep at least once before an important competition or game in the past  
114 year, they were required to complete a further four closed response questions.

115           The initial closed response question assesses the types of sleep problems the athlete  
116 experienced. The response options were; "problems falling asleep", "waking up at night",  
117 "waking up early in the morning", and "unpleasant dreams" with the first three options  
118 referring to typical sleep problems associated with insomnia. The second question addresses  
119 reasons for the sleep disturbance; "not used to surroundings", "noises in the room or from  
120 outside", "nervousness about competition/game", and "thoughts about the  
121 competition/game". The third question addressed the perceived consequences of poor sleep  
122 with options including; "no influence", "bad mood the following day", "increased  
123 daytime sleepiness", and "poorer performance in competition". In the fourth question,  
124 athletes report on the strategies used to deal with sleeping problems with responses; "no  
125 special strategy", "methods to relax", "sleeping pills", "reading", and "watching TV".

126           In the final section of the questionnaire, an additional series of questions were used  
127 to obtain information regarding general sleep habits and training. Within this section athletes  
128 answered questions such as; "If you have a late training session or game do you find it hard  
129 to sleep after?" and "Do you take sleeping medication?".

130           The validated Pittsburgh Sleep Quality Index (PSQI) has been used throughout  
131 numerous sleep studies as a standardised sleep questionnaire estimating general sleep  
132 quality,<sup>21</sup> however there has been limited use in athletes<sup>16</sup>. For the current study the

133 questionnaire was used to identify 'good' or 'poor' sleepers. Prior to filling out the PSQI  
134 athletes were notified that all answers were to indicate the most accurate reply for the  
135 majority of days and nights in the past month only. Seven component scores were generated  
136 (using a 0-3 scale): subjective sleep quality, sleep latency, sleep duration, habitual sleep  
137 efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. From  
138 the sum of the seven component scores a global score (range, 0-21) was calculated<sup>22, 23</sup>. If an  
139 athlete scored between 0-5 they were classed as a 'good sleeper' as specified by the PSQI  
140 and a score above 5 classed an athlete as a 'poor sleeper'<sup>21</sup>.

141 Differences for age, years in sport, practice hours per week and sleep per night  
142 between the groups for gender, sport and time of season the questionnaire was answered  
143 were analysed using an independent sample t-test for the continuous variables. The  
144 percentage of athletes who responded "yes" to reporting poor sleep the night before an  
145 important competition or game in the past year was calculated. For the "yes" respondents,  
146 associations between categorical variables for sex (female vs. male), sport groups (individual  
147 vs. team sports) and time of season the questionnaire was answered (in season vs. out of  
148 season) was calculated for each sleep disturbance question using a 2 x 2 frequency table and  
149 Pearson's chi-squared test ( $\chi^2$ ). To determine whether an association existed between  
150 athletes who reported "yes" or "no" to sleep disturbance prior to a competition and athletes  
151 who were classed as generally 'good' or 'poor' sleepers through the Pittsburgh Sleep Quality  
152 Index, a chi-squared test was calculated. A binary logistic generalized linear model was run  
153 to ascertain the effects of the dichotomised variables age, gender, sport and athletes in or out  
154 of season on the predicted likelihood of athletes having poor sleep prior to an important  
155 competition. All statistics were completed using SPSS<sup>®</sup> Statistics (version19, IBM<sup>®</sup>, USA)  
156 and R (R Foundation for Statistical Computing, Vienna) statistical software programs with  
157 significance set to  $p \leq 0.05$ .

158 **Results**

159 From the 283 Australian athletes sampled, 181 (64.0%) indicated they had slept  
160 worse than usual in the night(s) prior to an important competition or game over the past 12  
161 months. There were no significant differences between gender (62.4 % male vs. 65.9%  
162 female), sport (71.23 % individual vs. 61.4% team) or athletes currently in or out of season  
163 (61.3 % in-season vs. 69.1% out of season); (Table 3).

164 The 181 Australian athletes who reported worse sleep at least once prior to a  
165 competition or game answered further questions in relation to their sleep disturbances (Table  
166 3). Overall, the majority of athletes indicated they had “problems falling asleep” (82.1%)  
167 due to “thoughts about the competition/game” (83.5%) however (46.6%) believed this had  
168 “no influence” on their performance.

169 There was an association between genders for unpleasant dreams, with dreams  
170 affecting sleep in females (10%) more frequently than males (0%); ( $\chi^2_{(1)} = 9.16, p = 0.002$ ).  
171 In addition, females reported reading more frequently (32.6%) as a strategy to obtain  
172 improved sleep on the night prior to a competition than males (18.5%); ( $\chi^2_{(1)} = 4.51, p =$   
173 0.034). No further differences were found between gender.

174 There were no differences observed between individual versus team sport athletes  
175 for problems and reasons for sleep disturbance with both indicating internal factors  
176 “nervousness about the competition/game” and “thoughts about the competition/game” as  
177 the main reasons for their sleep disturbance (Table 3). An association ( $\chi^2_{(1)} = 8.36, p = 0.005$ )  
178 was found for individual athletes reporting worse sleep to have no influence on performance  
179 (63.5%) when compared with team sport athletes (39.7%). Increased daytime sleepiness was  
180 stated more frequently in team sport athletes (48.4%) compared with individual athletes  
181 (26.9%); ( $\chi^2_{(1)} = 6.97, p = 0.012$ ). Additionally, a higher percentage of team sport athletes  
182 (59.1%) reported having no special strategy to obtain better sleep on the night before an  
183 important competition or game compared with individual athletes (32.7%); ( $\chi^2_{(1)} = 9.87, p =$   
184 0.002). Individual athletes reported using methods to relax ( $\chi^2_{(1)} = 5.53, p = 0.024$ ) and



185 reading ( $\chi^2_{(1)} = 12.4, p = 0.001$ ) as strategies to enhance sleep more often than team sport  
186 athletes (Table 3).

187 There was an association between poor sleep responses prior to competition and the  
188 PSQI ( $\chi^2_{(1)} = 5.195, p = 0.002$ ) indicating the two variables are statistically independent of  
189 one another.

190 The logistic regression model which predicted the likelihood participants had poor  
191 sleep was statistically significant ( $\chi^2_{(3)} = 15.819, p = 0.001$ ). Of the four predictor variables,  
192 age, gender, sports and season, only two were statistically significant; age ( $p=0.019$ ) and  
193 sport ( $p=0.004$ ). Increasing age was associated with an increased probability of exhibiting  
194 poor sleep in individual sport athletes whereas team sport athletes' probability of poor sleep  
195 decreased with age (Figure 1).

196 General sleep disturbance percentages indicate 52.5% of athletes experience poor  
197 sleep post late game whilst 47.5% show no sleep disturbance. Following a rest day 28.4% of  
198 athletes indicate having sleep disturbance whilst 71.6% did not. Finally 27.7% of athletes  
199 experience sleep disturbance during heavy training periods.

200

## 201 Discussion

202 The purpose of this study was to understand the sleep complaints of elite Australian  
203 athletes prior to important competitions and games. The main findings were; 1) 64% of  
204 Australian athletes surveyed experienced sleep problems prior to a major competition at  
205 least once in the previous 12 months. The key sleep complaint reported was difficulty  
206 initiating sleep due to nervousness and thoughts prior to competition. 2) The perceived  
207 influence of poor sleep on performance varied between individual and team sport athletes. 3)  
208 When further examining individual and team sport variances, the percentage use of  
209 strategies was statistically different. 4) The predicted likelihood of sleep disturbance due to  
210 an athlete's age differed with individual and team sport athletes. 5) A novel finding was the  
211 sleep problems reported by athletes in this study were confined to competition periods only.

212 In the present study, we observed 64% of the athletes surveyed indicated sleep  
213 disturbance prior to important competition which supports previous anecdotal evidence. This  
214 finding is comparable to the occurrence of sleep complaints found in German athletes  
215 (65.8%) prior to major competitions<sup>6</sup>. The majority of Australian athletes who indicated  
216 experiencing worse sleep prior to competition reported internal factors as the main reason  
217 responsible (Table 3). Specifically, nervousness and thoughts about the competition were the  
218 most common reasons for sleep problems regardless of an athlete's gender or sport. This  
219 finding is consistent with previous research in both marathon runners<sup>7</sup> and German athletes<sup>6</sup>  
220 who reported experiencing anxiety and excessive thoughts prior to competition. Whilst  
221 external factors such as noise may impact sleep, our results confirm internal factors strongly  
222 influence sleep disturbance in the current athlete population.

223 Consequences of fragmented sleep on performance are of importance to athletes and  
224 coaches, as sleep restriction whether chronic or acute may have detrimental effects on health  
225 and performance<sup>24</sup>. In our study, the two most commonly reported consequences of sleep  
226 disruption were; 1) no perceived influence on performance (46.6%) and/or 2) increased  
227 daytime sleepiness (42.1%). The later finding is consistent with previous studies in athletes<sup>6</sup>  
228 and the general population<sup>24</sup> where daytime sleepiness was recognised as the most  
229 frequently described consequence of insufficient sleep. Interestingly, only 14% of all  
230 surveyed athletes believed reduced sleep directly resulted in worse performance during  
231 competition. Performance was not assessed during the study therefore there is little  
232 information to determine whether an athlete had an accurate perception of performance  
233 impacts.

234 Results indicate individual sport athletes are similar to team sport athletes in the  
235 reported occurrence of sleep complaints prior to major competitions. These findings contrast  
236 those by Erlacher et al.<sup>6</sup> who observed greater reporting of poor sleep in individual sport  
237 athletes compared with team sport athletes. This difference was explained by the lower  
238 pressure and anxiety experienced in team sports as these athletes, unlike individual sport  
239 athletes, are not solely responsible and accountable for their own results<sup>6</sup>. Although this

240 explanation is feasible our data does not support this hypothesis as we observed team sport  
241 athletes to report nervousness and thoughts prior to competition as reasons responsible for  
242 the poor sleep similar to the individual athletes. While additional research is needed to  
243 examine differences in sleep habits of individual versus team sport athletes to fully  
244 appreciate the diversity, our current data indicates sleep education through methods such as  
245 sleep hygiene (behaviours that are believed to promote improved quantity and quality of  
246 sleep<sup>25</sup> ) could provide benefits of sleep enhancement in both individual and team sport  
247 athletes.

248         Despite team and individual sport athletes reporting similar sleep problems and  
249 reasons responsible for sleep disturbance, team sport athletes reported a greater incidence of  
250 daytime sleepiness compared with individual sport athletes (Table 3). It is possible the  
251 greater daytime sleepiness in team sport athletes is due to a lack of sleep strategies utilised to  
252 overcome sleep complaints compared with individual sport athletes (Table 3). For instance,  
253 individual sport athletes reported more frequently the reliance on reading and/or methods to  
254 relax to combat sleep complaints in comparison with team sports athletes who were more  
255 likely to have no strategies in place (Table 3). Furthermore, as individual athletes indicated  
256 having a greater number of strategies to overcome sleep disturbance this possibly explains  
257 why these athletes reported sleeping problems to have little influence on their performance  
258 more frequently than their team sport counterparts.

259         Increasing age in individual sport athletes was associated with an increased  
260 likelihood of sleep disturbance prior to competition. Intuitively it could be hypothesised that  
261 sleep quality before competition would improve as an athlete aged due to being accustomed  
262 to the experience of competition however this does not seem to be the case. Defining normal  
263 sleep in athletes and differing age categories remains a challenge due to multiple factors  
264 contributing to poor sleep<sup>26</sup> . Indeed, age related differences in sleep have been documented;  
265 however, these changes are most prominent in individuals beyond 40 years of age thus,  
266 limiting the usefulness of this data in our athlete population<sup>27</sup> . The exact reason for the

267 increased likelihood of sleep disturbance in individual sport athletes as they age remains  
268 unknown and warrants further investigation.

269 Interestingly, a lack of association was observed between athletes who reported poor  
270 sleep prior to competition, from the Competitive Sports and Sleep Questionnaire and  
271 whether the athlete was classed as a “poor” sleeper in general, as determined by the  
272 Pittsburgh Sleep Quality Index. This finding implies that although an athlete may not be  
273 classed as a problematic sleeper on a day-to-day basis, sleep complaints may arise around  
274 competition periods that otherwise are not present. Indeed, in our athletes more than half  
275 reported sleep disturbance following a late game or training session. In addition, a smaller  
276 number indicated fragmented sleep following heavy training periods and days of rest. These  
277 findings highlight the need for caution when using a single subjective sleep quality  
278 questionnaire to assess an athletic population, as global sleep quality assessments may not  
279 display the same efficacy as with the general population, due to situational stressors and  
280 events athletes’ encounter.

281

## 282 **Conclusion**

283 Our findings highlight the majority of Australian athletes’ surveyed subjectively  
284 indicated sub-optimal sleep surrounding important competitions mainly due to nervousness  
285 and thoughts prior to competition. With evidence suggesting athletes sleep poorly pre-  
286 competition more research is needed to investigate the effects of acute sleep loss on athletic  
287 performance. The current sleep strategy results were concerning with few athletes aware of  
288 sleep strategies to utilise during these critical competition periods. Whilst no gender  
289 differences were exhibited, there were age and team sport versus individual sport differences  
290 which should be considered. The poor sleep reported during competition appears to be  
291 situational and not associated with poor sleep in general. The current study highlights the  
292 need for individual monitoring of athlete sleep habits and the need for increased sleep  
293 hygiene education within both individual and team sports.

294

295 **Practical Implications**

- 296       • Both team sport and individual sport athletes would benefit from sleep education
- 297       • Athletes should be made aware and educated on strategies such as sleep hygiene to
- 298       assist them to sleep around important competitions
- 299       • Sleep strategies should specifically focus on combatting nervousness and thoughts
- 300       prior to competition in athletes

301

302 **Conflict of Interest**

303 No competing agreements, professional relationships and financial interests existed where a

304 third party may benefit from the presented results.

305

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309

## References

- 310 1. Davison RCR, Williams AM. The use of sports science in preparation for  
311 Olympic competition. *J Sports Sci* 2009;1363-1365.
- 312 2. Vaile J, Halson, S, Graham, S. Recovery review- Science vs practice. *J*  
313 *Aust Strength Cond* 2010;Supp 2:5-21.
- 314 3. Leeder J, Glaister M, Pizzoferro K et al. Sleep duration and quality in  
315 elite athletes measured using wristwatch actigraphy. *J Sports Sci*  
316 2012;30(6):541-545.
- 317 4. Halson SL. Nutrition, sleep and recovery. *Eur J Sport Sci* 2008;8(2):119-  
318 126.
- 319 5. Halson SL. Sleep and the elite athlete. *Sports Science* 2013;26(113):1-4.
- 320 6. Erlacher D, Ehrlenspiel F, Adegbesan OA et al. Sleep habits in German  
321 athletes before important competitions or games. *J Sports Sci* 2011;29(8):859-  
322 866.
- 323 7. Lastella M, Lovell GP, Sargent C. Athletes' precompetitive sleep  
324 behaviour and its relationship with subsequent precompetitive mood and  
325 performance. *Eur J Sport Sci* 2012(ahead-of-print):1-8.
- 326 8. Cook CJ, Crewther BT, Kilduff LP et al. Skill execution and sleep  
327 deprivation: effects of acute caffeine or creatine supplementation-a randomized  
328 placebo-controlled trial. *J Int Soc Sports Nutr* 2011.
- 329 9. Waterhouse J, Atkinson G, Edwards B et al. The role of a short post-  
330 lunch nap in improving cognitive, motor, and sprint performance in  
331 participants with partial sleep deprivation. *J Sports Sci* 2007;25(14):1557-1566.
- 332 10. Skein M, Duffield R, Edge J et al. Intermittent-sprint performance and  
333 muscle glycogen after 30 h of sleep deprivation. *Med Sci Sports Exerc*  
334 2011;43:1301-1311.
- 335 11. Oliver SJ, Costa RJ, Laing SJ et al. One night of sleep deprivation  
336 decreases treadmill endurance performance. *Eur J Appl Physiol*  
337 2009;107(2):155-161.
- 338 12. Taheri M, Arabameri E. The effect of sleep deprivation on choice  
339 reaction time and anaerobic power of college student athletes. *Asian Journal of*  
340 *Sports Medicine* 2012;3(1):15-20.
- 341 13. Abdelmalek S, Chtourou H, Aloui A et al. Effect of time of day and  
342 partial sleep deprivation on plasma concentrations of IL-6 during a short-term  
343 maximal performance. *Eur J Appl Physiol* 2013;113(1):241-248.

- 344 14. Underwood J. Sleep Now Clearly a Predictor of Performance *Coaches*  
345 *Plan* 2010;17(1):31-34.
- 346 15. Blumert PA, Crum AJ, Ernsting M et al. The Acute Effects of Twenty-  
347 Four Hours of Sleep Loss on the Performance of Nationalcaliber Male  
348 Collegiate Weightlifters. *The Journal of Strength & Conditioning Research*  
349 2007;21(4):1146-1154.
- 350 16. McMorris T, Graydon J. The effect of exercise on cognitive performance  
351 in soccer-specific tests. *J Sports Sci* 1997;15(5):459-468.
- 352 17. Davenne D. Sleep of athletes-problems and possible solutions. *Biol*  
353 *Rhythm Res* 2009;40(1):45-52.
- 354 18. Netzer NC, Kristo D, Steinle H et al. REM sleep and catecholamine  
355 excretion: a study in elite athletes. *Eur J Appl Physiol* 2001;84(6):521-526.
- 356 19. Samuels C. Sleep, recovery, and performance: the new frontier in high-  
357 performance athletics. *Phys Med Rehabil Clin N Am* 2009;20(1):149-159.
- 358 20. Driver HS, Rogers GG, Mitchell D et al. Prolonged endurance exercise  
359 and sleep disruption. *Med Sci Sports Exerc* 1994;26(7):903-907.
- 360 21. Buysse DJ, Reynolds CF, Monk TH et al. The Pittsburgh Sleep Quality  
361 Index: a new instrument for psychiatric practice and research. *Psychiatry*  
362 *research* 1989;28(2):193-213.
- 363 22. King AC, Oman RF, Brassington GS et al. Moderate-intensity exercise  
364 and self-rated quality of sleep in older adults. A randomized controlled trial.  
365 *JAMA* 1997;277(1):32-37.
- 366 23. King AC, Pruitt LA, Woo S et al. Effects of moderate-intensity exercise  
367 on polysomnographic and subjective sleep quality in older adults with mild to  
368 moderate sleep complaints. *J Gerontol A Biol Sci Med Sci* 2008;63(9):997-1004.
- 369 24. Goel N, Rao H, Durmer JS et al., editors. Neurocognitive consequences  
370 of sleep deprivation. *Semin Neurol*; 2009: NIH Public Access.
- 371 25. Stepanski EJ, Wyatt JK. Use of sleep hygiene in the treatment of  
372 insomnia. *Sleep medicine reviews* 2003;7(3):215-225.
- 373 26. Dijk DJ, Archer SN. PERIOD3, circadian phenotypes, and sleep  
374 homeostasis. *Sleep Med Rev* 2010 Jun;14(3):151-160.
- 375 27. Van Cauter E, Leproult R, Plat L. Age-related changes in slow wave  
376 sleep and REM sleep and relationship with growth hormone and cortisol levels  
377 in healthy men. *JAMA: the journal of the American Medical Association*  
378 2000;284(7):861-868.  
379

**Tables**

Table 1. Distribution of athletes by sport.

Individual	Team
Athletics $n=21$	Basketball $n=14$
Canoe/Kayak $n=6$	Football (soccer) $n=24$
Cycling $n=17$	Hockey $n=30$
Gymnastics $n=3$	Netball $n=30$
Moguls $n=1$	Rugby League $n=15$
Rowing $n=4$	Rugby Sevens $n=44$
Sailing $n=2$	Softball $n=14$
Short Track Speed Skating $n=1$	Volleyball $n=10$
Ski Cross $n=3$	Waterpolo $n=4$
Surf Life Saving $n=1$	Wheelchair Basketball $n=19$
Swimming $n=9$	Wheelchair Rugby $n=6$
Tennis $n=3$	
Triathlon $n=1$	
Power Lifting $n=1$	



**Table 2.** Characteristics of athletes by gender, sport and season (mean  $\pm$  s).

	Overall ( <i>n</i> =283)	Gender		Sport		Season	
		Male	Female	Individual	Team	In-Season	Out of Season
		( <i>n</i> =126)	( <i>n</i> =157)	( <i>n</i> =73)	( <i>n</i> =210)	( <i>n</i> =187)	( <i>n</i> =96)
Age	24.1 $\pm$ 5.1	24.0 $\pm$ 5.5	24.2 $\pm$ 4.9	24.4 $\pm$ 5.8	23.9 $\pm$ 4.9	24.5 $\pm$ 5.2*	23.2 $\pm$ 4.8
Years in Sport	11 $\pm$ 6	11 $\pm$ 7	11 $\pm$ 6	11 $\pm$ 6.0	11 $\pm$ 7	11 $\pm$ 6	11 $\pm$ 6
Practice hours per week (hrs:mins)	16:42 $\pm$ 6:42	16:42 $\pm$ 6:00	16:48 $\pm$ 7:12	23:00 $\pm$ 7:30*	14:36 $\pm$ 4:42	16:06 $\pm$ 6:06*	18:00 $\pm$ 7:30
Sleep duration per night (hrs:mins)	7:42 $\pm$ 0:54	7:48 $\pm$ 0:54	7:36 $\pm$ 0:54	7:48 $\pm$ 1:00	7:36 $\pm$ 0:54	7:42 $\pm$ 0:54	7:42 $\pm$ 1:00

\* Difference ( $p < 0.05$ ) between groups within category

	All Participants		Gender				Sport				Season			
	Absolute	Frequency (%)	Male (%)	Female (%)	Chi square	p-value	Individual (%)	Team (%)	Chi square	p-value	Out of Season (%)	In Season (%)	Chi square	p-value
Overall	181	64.0	65.9	62.4	0.55	0.619	71.2	61.4	0.13	0.158	69.1	61.3	0.20	0.240
<b>“What kinds of problems did you experience with your sleep prior to an important competition or game?”</b> <i>n=179</i>														
Problems falling asleep	147	82.1	80.7	83.3	0.21	0.698	80.7	82.7	0.09	0.831	86.2	79.8	1.13	0.318
Waking up early in the morning	48	26.8	24.1	29.2	0.58	0.501	32.7	24.4	1.29	0.269	24.6	28.1	0.25	0.726
Waking up at night	68	38.0	32.5	42.7	1.96	0.169	44.2	35.4	1.21	0.310	43.1	35.1	1.12	0.337
Unpleasant dreams	10	5.6	0	10	9.16	0.002*	4	6	0.42	0.726	6	5	0.06	1.000
Not feeling refreshed in morning	65	36.3	34.9	37.5	0.13	0.757	32.7	37.8	0.42	0.608	30.8	39.5	1.36	0.262
<b>“What reasons were responsible for your sleeping problems prior to an important competition or game?”</b> <i>n=176</i>														
Thoughts about competition	147	83.5	82.9	84.0	0.16	0.837	76.5	86.4	2.59	0.120	83.1	83.8	0.01	1.000
Nervousness about competition	77	43.8	42.7	44.7	0.07	0.877	49.0	41.6	0.81	0.405	44.6	43.2	0.03	0.876
Not used to surroundings	39	22.16	23.3	22.3	0.02	1.000	21.6	23.3	0.05	1.000	26.2	20.7	0.69	0.458
Noises in room or outside	31	17.6	15.0	19.0	0.75	0.428	26.0	14.0	3.62	0.076	15.0	18.0	0.31	0.666
	All Participants		Gender				Sport				Season			
	Absolute	Frequency (%)	Male (%)	Female (%)	Chi square	p-value	Individual (%)	Team (%)	Chi square	p-value	Out of Season (%)	In Season (%)	Chi square	p-value
<b>“In what manner did the sleeping problems influence your performance during the competition or game?”</b> <i>n=178</i>														
No influence	83	46.6	48.2	45.3	0.15	0.764	63.5	39.7	8.36	0.005*	56.9	40.7	4.36 17	0.043*
Increased daytime sleepiness	75	42.1	36.1	47.4	2.29	0.171	26.9	48.4	6.97	0.012*	35.4	46.0	1.91	0.207
Bad mood the following day	24	13.4	13.3	13.7	0.01	1.000	11.5	14.3	0.24	0.810	4.6	18.6	6.90	0.011*

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**Table 3.** Absolute and relative number of responses for each person who states, “Yes” they have had disrupted or fragmented sleep prior to an important competition or game in the last 12 months.

**Figure 1.** The predicted probability of sleep difficulties prior to an important competition for individual and team sport athletes' based on age. Predicted probabilities and 95% confidence intervals are displayed.

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