

1 **SLEEP AND PSYCHOLOGICAL FACTORS ARE ASSOCIATED WITH MEETING**  
2 **DISCHARGE CRITERIA TO RETURN TO SPORT FOLLOWING ACL**  
3 **RECONSTRUCTION IN ATHLETES**

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16 **ABSTRACT**

17 **INTRODUCTION:** This study aimed to determine if sleep quality and psychological factors

18 were associated with time to meet the discharge criteria to return to sport (RTS) following

19 anterior cruciate ligament reconstruction (ACL-R) among athletes experiencing better quality of

20 sleep and psychological responses returning faster to full activity.

21 **METHOD:** A cohort-study design included 89 athletes following ACL-R. Each participant

22 completed a battery of questionnaires at 6 different time points: within 3 days of injury

23 occurrence and at post-surgery (1.5m, 3m, 4.5m, 6m and when discharge criteria were met).

24 Assessment included sleep quality and quantity, symptoms of depression, anxiety, stress,

25 psychological readiness to RTS and fear of re-injury. The primary outcome was the time needed  
26 to meet all discharge criteria to RTS.

27 **RESULTS:** Sleep parameters and psychological factors were not associated with time to meet  
28 the discharge criteria to RTS. However, athletes that had low anxiety and insomnia scores at  
29 baseline and better sleep quality at 3m, 4.5m, 6m and at discharge were more adherent to the  
30 rehabilitation program and more likely to meet the RTS discharge criteria OR 1.2 (95% CI 1.0-  
31 1.34), 1.3 (95% CI 1.1, 1.7) and 2.0 (95% CI 1.1-3.4) respectively.

32 **CONCLUSIONS:** Sleep quality and psychological factors were not associated with time to  
33 meet the discharge criteria to RTS but impacted whether athletes adhered and completed their  
34 rehabilitation program or not. Monitoring sleep quality and psychological factors of athletes  
35 before and following ACL-R surgery is important to identify athletes who could have difficulties  
36 in adhering to and completing their rehabilitation program to RTS.

37 **KEYWORDS:** PSQI; Injury; Psychology; Athletes; Sport.

38

39     **INTRODUCTION**

40     Sleep is a basic physiological need representing approximately one third of the human life cycle  
41     [1]. The National Sleep Foundation recommends 8 to 10 hours of sleep per night for adolescents  
42     and adults[2] with no specific recommendations for athletic populations. Failing to adhere to the  
43     recommended sleep durations can results in negative health outcomes such as cardiovascular  
44     disease, diabetes, obesity and/or depression [3]. Moreover, poor sleep across several days/weeks  
45     may potentially predispose athletes to injury with the increase of chronic fatigue levels [4]. In  
46     addition and more specifically, deep-sleep has been shown to be essential for injury recovery and  
47     for accelerated healing [5].

48     Anterior cruciate ligament (ACL) rupture is the most common major ligament injury in athletes  
49     for which surgery is routinely performed[6]. Adequate post-operative rehabilitation lasting  
50     between six and twelve months is essential to ensure safe recovery [7, 8], and athletes are  
51     expected to follow a standardized daily physiotherapy program until they can return to sport  
52     (RTS). RTS is an important outcome when evaluating the success of ACL-R surgery in  
53     athletes[9]. However, it has been reported that prolonged stays in hospital or rehabilitation  
54     centers are associated with the disruption of the sleep-wake cycle [10] questioning if those  
55     disruptions affect injury recovery and RTS. It has been reported that 50% of athletes who  
56     undergo an ACL-R (and were free from muscle soreness) have suffered sleep disturbances and

57 report poor sleep quality [11]. Therefore, sleep appears to be an important factor to evaluate  
58 during the rehabilitation phase post- ACL-R.

59 Even if both surgery and rehabilitation are effectively performed, two-thirds of patients may not  
60 return to their preinjury sport level 12 months after ACL-R [12-14] . For an athlete population  
61 this is even more important not only from a performance prospective, but also because athletes  
62 who do not fully recover before returning to sport after ACL-R have a four times higher risk of  
63 reinjury, i.e. sustaining an ACL graft rupture [15]. Further, even athletes with good knee  
64 function do not often return to their previous level of sports participation after ACL-R, and the  
65 rate of return to the pre-injury level and competitive sport remains very low[9]. This suggests  
66 that factors other than knee function may influence the RTS. In a recent study, Kosy et  
67 al.,2019[16] investigated the ability of athletes to RTS after ACL-R and the reasons associated  
68 with failure to RTS. They concluded that failure was associated with physical symptoms in 67%  
69 of the athletes and to psychological factors in 77% of them, with the main factors being anxiety,  
70 depression and fear or re-injury. Suffering from anxiety and fear of re-injury often results in  
71 higher levels of fear of movement (Kinesiophobia) and is generally exacerbated once an athlete  
72 has been cleared to RTS [16, 17]. Finally, depression that can be as high as 42% in patients  
73 having undergone ACL-R, and can be aggravated by the decreased quality of sleep during  
74 rehabilitation with a significant resulting influence on knee function outcomes [18, 19].

75 In order to take into consideration these psychological factors and optimize RTS [20], a  
76 commonly used discharge criteria after ACL-R is the psychological readiness to RTS [21]. In a  
77 recent study Kitaguchi et al., (2019) [22] compared two groups of athletes, those who returned to  
78 sport one year post ACL-R and those who didn't. They determined that single-leg hop and  
79 psychological readiness to RTS at 6 months were the main factors that were associated with a  
80 greater risk of unsuccessful RTS at 1-year post-surgery.

81 Taken together these studies suggest that athletes with maladaptive psychological responses to  
82 injury and/or having a poor sleep quality and/or quantity may be at risk for suboptimal recovery  
83 and resulting delay in the time to RTS [23]. Recently, Webster et al., (2018) [24] acknowledged  
84 that factors that contribute to the psychological status of athletes who RTS after ACL-R might be  
85 different from those of athletes who do not RTS.

86 The purpose of the present study was therefore to investigate the impact of sleep and  
87 psychological factors on the athletes' rehabilitation outcome following ACL-R. We hypothesized  
88 that sleep quality and psychological factors will be associated with time to meet the discharge  
89 criteria to RTS with the athletes experiencing better quality of sleep and psychological responses  
90 returning faster to full activity.

91

92 **MATERIALS AND METHODS**

93 **Participants**

94 Eighty-nine male athletes who had undergone ACL reconstruction from May 2015 to September  
95 2017 gave written informed consent to participate to this study. Ethical approval was obtained  
96 from the Ethics Committee of the Anti-Doping Lab Qatar Institutional Review Board (IRB  
97 application number F2014000063). The study was designed in accordance with the 1964 Helsinki  
98 Declaration. The inclusion criteria were male athletes having undergone an ACL reconstruction  
99 surgery: age above 18 to 37 years; (oldest participant); full time athletes belonging to any sport;  
100 only male athletes were included due to unavailability of female athletes; all athletes who stopped  
101 their rehabilitation program before 6 months were excluded from the analysis.

102 **Procedure**

103 The participants were assessed for sleep and psychological factors by two clinicians in a quiet  
104 environment at 6 time points: (i) within 3 days of post-injury incident: retrospective assessment  
105 of sleep (1month prior to) and psychological factors (1week prior to ACL injury) (baseline), (ii)  
106 at 1.5 month (1.5m), (iii) 3 months (3m), (iv) 4.5 months (4.5m), (v) 6 months (6m) post-surgery,  
107 and (vi) when meeting the discharge criteria to RTS (post-surgery assessments were performed  
108 every six weeks as per standard ACL protocol till meeting discharge criteria to RTS). Assessment  
109 included sleep quality and quantity and psychological factors using face-to-face administered  
110 questionnaires (see below). The RTS where the athlete could return to unrestricted sports

111 activities in his respective sport club were criteria-based, not time-based. Athletes were  
112 discharged to RTS only upon completion of eight standardized discharge criteria : <10%  
113 difference between legs for the isokinetic force of the quadriceps at  $60^{\circ}.s^{-1}$ , hamstring/quadriceps  
114 ratio >55% during the isokinetic testing at  $60^{\circ}.s^{-1}$ , <10% difference between legs during the hop-  
115 testing, all tests performed pain-free ,stable knee, educated on prevention and maintenance and  
116 completed surgical review [15]. For the analysis, athletes were assigned to two groups: (i)  
117 meeting the discharge criteria group (MDG) to RTS and (ii) did not meet the discharge criteria  
118 group (NDG) to return to sport. In our study, the treatment adherence was measured by  
119 physiotherapy appointments attendance and eventual withdrawal from the Rehab program.  
120 The discharge dates were different from one athlete to another as surgery dates varied. In  
121 addition, it is possible that athletes did meet the discharge criteria to RTS well ahead of the  
122 assessments, which were scheduled every six weeks.

### 123 **Sleep assessment**

124 The Pittsburgh Sleep Quality Index (PSQI) was used to assess subjective sleep quality over the  
125 previous month (pre-injury). The PSQI consists of 19 items to assess seven components of sleep:  
126 quality, duration, latency, efficiency, disturbances, use of sleep drugs and daytime dysfunction.  
127 The PSQI provides score of sleep quality and quantity (range: 0–21) with higher scores indicating

128 poor sleep quality or more sleep difficulties. A PSQI threshold score  $\geq 5$  was used to indicate poor  
129 sleep quality and has been used in similar populations [25].

130 The Insomnia Severity Index (ISI) was used to assess subjective symptoms of insomnia over the  
131 previous month. It consists of seven questions rated on a scale ranging from 0 to 4, with a total  
132 score of up to 28 points, with higher scores indicating insomnia. Commonly adopted thresholds  
133 were used, with  $\geq 11$  suggesting subthreshold insomnia and  $\geq 15$  suggesting clinical insomnia  
134 [26].

135 The Epworth Sleepiness Scale (ESS) was used to measure daytime sleepiness in eight different  
136 situations and activities of everyday life (e.g., watching TV, reading) within the previous month.  
137 Each item is measured on a scale of 0 (“would never doze”) to 3 (“high chance of dozing”) and  
138 total scores can range from 0 to 24 [27]. Normal ESS values range from 0 to 8 ; however, a cut-  
139 off of  $>8$  indicates excessive daytime sleepiness in clinical sleep disorders populations [28].

#### 140 **Psychological states assessment**

141 The Depression, Anxiety & Stress Scale (DASS-21): a short form of DASS, was used to assess  
142 Depression (DASS-D), Anxiety (DASS-A), and Stress (DASS-S) over the previous week through  
143 seven items, responses ranged was from 0 (did not apply to me at all) to 3 (applied to me very  
144 much). The intensity of any of the three conditions are determined by the sum scores of responses  
145 to its 7-item subscale [29].



146 Anterior Cruciate Ligament RTS After Injury (ACL-RSI) was used to measure psychological  
147 readiness to RTS after ACL-R. The ACL-RSI is a 12-items scale that measures 3 types of  
148 responses believed to be associated with the resumption of sport following athletic injury:  
149 emotions, confidence in performance, and risk appraisal. The total score was obtained by adding  
150 the values of the 12 responses then calculating a percentage. High scores correspond to readiness  
151 to RTS [30].

152 Tampa Scale for Kinesiophobia (TSK) is a 17 items questionnaire that was used to assess the  
153 subjective rating of Kinesiophobia or fear of movement. The TSK is a self-completed  
154 questionnaire and the range of scores is from “17” to “68” where the higher scores indicate an  
155 increasing degree of Kinesiophobia [31].

## 156 **Statistical Analysis**

157 All data were coded and entered to the SPSS software v21.0. Continuous variables were  
158 described as mean $\pm$ SD and categorical variables were summarized as frequency and percentage.  
159 All continuous variables were tested for normality and presence of outliers using Shapiro-Wilk  
160 test. The Pearson’s correlation coefficient was used to describe the correlation of sleep, and  
161 psychological factors at baseline, 1.5m, 3m, 4.5m, 6m and at discharge among those who met the  
162 discharge criteria and returned to sport. An independent samples t-test was used to compare the  
163 means of sleep indices and psychological factors at all assessment points between athletes who

164 met the discharge criteria MDG compared with those who did not meet them NDG. Factors that  
165 were significantly associated with meeting the discharge criteria in the univariate analysis were  
166 added to a binary logistics regression separately for each time point. Odds ratio (OR) with 95%  
167 confidence intervals (CI) were reported. A  $p < 0.05$  was considered as threshold for statistical  
168 significance.

169

## 170 **RESULTS**

171 Total 89 athletes aged  $23.8 \pm 5.3$  years were included (height  $177.86 \pm 8.53$  cm and weight  $77.70 \pm$   
172  $12.38$  kg) with  $12.63 \pm 5.44$  years of experience in their respective sports. Most athletes were  
173 football players (61.8%), playing in first (68.5%), second Division (12.4%), and amateurs  
174 (19.1%), with 10 to 14 hours of training and match per week. Participants were Arabs (66.3%),  
175 Africans (19.1%), Caucasians (6.7%) and Asians (7.9%) (Table 1). The mechanism of ACL  
176 injury was either contact (33.3%) or non-contact (66.7% of the 89 cases). The grafts used during  
177 surgery were either hamstring (HS) 57.3%, bone to bone (BTB) 40.4% or quadriceps tendon graft  
178 1.1%.

179 For the compliance with the administration of the battery of questionnaires, of the 89 athletes, 59  
180 (66.2%) completed the battery at 3 days of post-injury (baseline), 56 (62.9%) at 1.5m, 71 (79.7%)  
181 at 3m, 46 (51.6%) at 4.5m, 53 (59.5%) at 6m. For the post 6 months' period, the following data

182 do not comprise the participants who were discharged: 46 (51.7%) at 7.5m, and 25 (28.1%) at 9  
183 m. At 9 and 24 m the participation rate was low (8 to 1 participant, respectively).

184

185 Of the 89 athletes, 46(51.7%) met the discharge criteria to RTS (MDG). 7 (7.9%) athletes self-  
186 discharged prior to six months and 31(34.8%) athletes self-discharged after 6 months without  
187 meeting the discharge criteria to RTS (NDG) (Table 1). The seven athletes who self-discharged  
188 themselves against hospital medical advice prior to six months and other 5 athletes who either  
189 returned back to home country for treatment or had reinjury were excluded from subsequent  
190 analysis. The average follow-up duration for MDG was  $274.1 \pm 87.8$  days. The 31 athletes that  
191 self-discharged themselves without meeting the discharge criteria (NDG) had a post-surgery  
192 follow-up time of  $312.4 \pm 115.3$  days.

193

194 There was no correlation between either sleep or psychological factors with time to meet the  
195 discharge criteria to RTS for the MDG (Table 2). At 3m, 4.5m, and 6m time points the sleep  
196 quality was significantly better among MDG compared to NDG ( $p < 0.05$ ). In addition, MDG had  
197 significantly lower insomnia index compared to baseline, at 3 and 4.5 months (Table3).

198 The depression, anxiety and stress assessments at baseline were significantly higher among NDG  
199 compared to MDG ( $p < 0.05$ ) and NDG had higher insomnia score than MDG ( $ISI = 12.1 \pm 4.2$  vs  
200  $7.6 \pm 4.5$  for NDG and MDG, respectively,  $p = 0.001$ ).

201 Athletes with good quality of sleep and positive psychological factors at baseline were more  
202 likely to complete their rehabilitation program and meet the discharge criteria to RTS (MDG).

203 Logistic regression analysis showed that PSQI at 3m (OR 1.33 (95% CI 1.1-1.7), at 4.5m (OR  
204 2.0 (95% CI 1.1-3.4), at 6m post-surgery (OR 1.4 (95% CI 1.0-1.9) and at discharge (OR 1.2  
205 (95% CI 1.0-1.5) were the main factor for probability of meeting discharge criteria to RTS.

206 Lower Anxiety (OR 1.17 (95% CI 1.0-1.3) and insomnia (OR 1.15 (95% CI 1.0-1.3) at baseline  
207 were also predictive of meeting discharge criteria to RTS (Table 4).

208

## 209 **DISCUSSION**

210 The aim of the present study was to determine if sleep quality and psychological factors were

211 associated with time to meet the discharge criteria to return to sport RTS following ACL-R

212 among athletes experiencing better quality of sleep and psychological responses returning faster

213 to full activity. The main findings were: (i) sleep quality and psychological factors were not

214 associated with time to meet the discharge criteria to RTS, but (ii) lower scores in anxiety and

215 insomnia prior to injury occurrence, and better sleep quality during rehabilitation were associated  
216 with athletes' adherence to rehabilitation program until meeting the discharge criteria to RTS.

217 Previous studies have suggested that a lack of sleep can affect an athlete's recovery by altering  
218 their post-exercise endocrine response and may promote muscle loss and prevent muscle  
219 recovery after injury or exercise-induced injury [32]. Although, these variables were not  
220 measured during our research we could argue that the lack of sleep and/or its decreased quality  
221 may have influenced these processes and affected the athletes' recovery. Furthermore, there is  
222 evidence that sleep helps healing and improving tissue growth and recovery from injury [33].

223 Moreover, the post-operative period has been associated with issues related to falling asleep and  
224 reduced duration of sleep that adversely affect postoperative recovery of patients [34]. A recent  
225 review has suggested that healthy elite athletes generally experience sleep disturbances  
226 characterized by symptoms of longer sleep latencies, higher sleep fragmentation, non-restorative  
227 sleep, and excessive daytime fatigue [35]. These disturbances are likely to be exacerbated after  
228 injury and during post-surgery rehabilitation due to the potential addition of pain which has been  
229 identified as the most common cause of sleep disturbance post-surgery [36].

230 In the present study, at 1.5m post-surgery, the PSQI scores for both NDG and MDG were higher,  
231 indicating a poor quality of sleep probably due to the pain experienced by ACL athletes at this  
232 stage (Table 3). However, the present findings showed that none of the sleep parameters at

233 baseline, 1.5m, 3m, 4.5m, 6m and discharge were associated with time to meet the discharge  
234 criteria to RTS. Thus, the present study does not support the research findings stating the  
235 importance of sleep and psychological factors for a faster recovery[37, 38].

236 In addition to sleep, psychological factors are important following injury, during rehabilitation  
237 and contribute to the overall quality and progression of rehabilitation and were shown to  
238 detrimentally affect recovery time and RTS[39]. However, in our study psychological factors,  
239 including anxiety, stress and depression were not associated with the time to recovery. Taken  
240 together, these results do not support the hypothesis that sleep quality and psychological factors  
241 are associated with time to meet the discharge criteria to RTS.

242 Previous studies suggest that psychological factors such as motivation, confidence, self-efficacy,  
243 optimism, and lower fear of re- injury are associated with the likelihood of returning to the pre-  
244 injury level following ACL reconstruction [40]. This is supported by our findings that showed  
245 that NDG group had higher depression, anxiety and stress scores at baseline assessment, 3m and  
246 4.5m and also higher stress and anxiety scores at 6m post-surgery. This timeline of psychological  
247 factors, is also in line with previous literature suggesting increases in depression, tension and  
248 anger reported immediately after athletic injury and at later stages in recovery [17].

249 However, unlike other studies we did not observe an improvement in these psychological factors  
250 as rehabilitation progressed until the last phases where these should generally be compromised by

251 the fear of re-injury at the RTS phase [41]. This discrepancy in the results might be related to the  
252 poor adherence to the rehabilitation program of the NDG, whom progress would have been  
253 slower than expected and therefore potentially promoting higher levels of psychological  
254 depression, anxiety and stress.

255 The second novelty of our findings is that other than the psychological factors athletes that had  
256 better sleep quality at 3m, 4.5m, 6m and at discharge were more adherent to the rehabilitation  
257 program and more likely to meet the RTS discharge criteria. Sports medicine personnel reports,  
258 suggest that low or non-adherence to the rehabilitation program post-injury can be an issue  
259 compromising recovery. Some authors have reported that adherence to sport injury rehabilitation  
260 rates range from 40% to 91%. [42] . Our findings (51.7%) of adherent athletes to rehabilitation  
261 program fall within the latter rates.

262 The current results support a recent review and meta-analysis showing that both positive affective  
263 responses and rehabilitation adherence were related to a successful RTS after a sport injury [43].  
264 Indeed, the NDG had significantly higher attendance, reported negative psychological factors at  
265 baseline and self-discharged themselves before meeting the discharge criteria to RTS. Pizzari et  
266 al. [44] investigated the relationship between adherence to rehabilitation programs after ACL-  
267 reconstructive surgery and 6 knee-function scales and 2 hop tests. They found a significant  
268 relationship between home-exercise adherence and rehabilitation outcomes for participants under

269 30 years of age (Spearman's correlation coefficients  $r_s = .33 - .44$ ) but none with physical  
270 therapy appointments. Our results add that the adherence to physiotherapy appointments until  
271 meeting discharge criteria to RTS in athletes may also determine the success of the rehabilitation  
272 programs. This is in accordance with Brewer et al. [45] who found that greater attendance at  
273 rehabilitation sessions following ACL-R led to more positive outcomes at 6 months' post-  
274 surgery. The discrepancies across studies on adherence may be the result of the complexity in the  
275 adherence outcome relationship and the multifaceted nature of adherence.

276 In this context, a review has identified different barriers (bio-psycho-social) to musculoskeletal  
277 physiotherapy treatment adherence including: low levels of physical activity at baseline or in  
278 previous weeks, low in-treatment adherence to exercise, low self-efficacy, depression, anxiety,  
279 helplessness, poor social support or activity, greater perceived number of barriers to exercise and  
280 increased pain levels during exercise [46]. The findings of the present study add to these findings  
281 that higher anxiety and insomnia at baseline, poor quality of sleep at 3m, 4.5m ,6m post-surgery  
282 and at discharge may also compromise adherence to rehabilitation following ACL-R.

283 In fact, the current data suggest that adherence might be the mediating factor between  
284 psychological factors, sleep quality and quantity and the rehabilitation programs' outcomes.

285 Indeed, using logistic regression, our results showed that sleep quality at baseline, 3m, 4.5m, 6m  
286 post-surgery and at discharge assessment were important factors associated with patient's



287 adherence to complete their rehabilitation program until meeting the discharge criteria to RTS. At  
288 baseline assessment, lower scores in anxiety was also associated with high odds for meeting  
289 discharge criteria.

290 The main findings of the present study were that sleep quality and psychological factors were not  
291 associated with time to meet the discharge criteria to RTS, however low anxiety and insomnia  
292 scores at baseline and sleep quality at post-surgery were predictive factors of athletes' adherence  
293 to rehabilitation program until meeting the discharge criteria to RTS.

294 This highlights the need to provide consistent psychological monitoring and support to athletes  
295 and a close monitoring of sleep before and during rehabilitation. Indeed, the present study shows  
296 that simple psychological assessments of anxiety, stress and depression and sleep monitoring of  
297 athletes could alert the health practitioners about the threat of poor adherence and consequently  
298 poor outcome of the rehabilitation program following ACL-R. This would allow to eventually put  
299 in place the adequate counter measures to hopefully help athletes to successfully RTS.

### 300 **Study Limitation**

301 Although, a cohort study design with lengthy and multiple follow-up of only athletes is one of the  
302 strengths of the study, it was limited to small sample size of 89 athletes. Future studies should  
303 consider the relatively high dropout rate of ACL injured athletes from their rehabilitation  
304 programs. The present study could not determine if athletes who did not adhere to the

305 rehabilitation program or who did not complete it may have been at a higher risk of ACL re-  
306 injury as post-RTS as ACL re-injuries were out of scope.

307 The sleep measurements were limited to subjective measures (sleep questionnaires). Actigraphy  
308 devices and sleep diaries would have provided complementary valuable information, albeit long  
309 term studies using such tools show a high drop-out. In addition to that, one of weaknesses of the  
310 PSQI is that it does not capture daytime naps. Recent studies reported that naps after sleep  
311 deprivation improved some sleep parameters, perception of fatigue and physical performances,  
312 cognitive function measures and mood and oxidative stress [47]. Therefore, future studies should  
313 track eventual naps that would complement night sleep, potentially influencing the outcome of  
314 the studies. The psychological initial assessment was performed within 3 days of injury, to assess  
315 baseline psychological factors (independent of the injury), but despite the precautions taken  
316 during these assessments, we cannot rule out that some of the answers were impacted by the  
317 actual status of recently injured athlete.

318 Finally, all the baseline as well as post-surgery findings were discussed with the athletes as an  
319 education tool to enhance awareness of sleep and mental health condition and may have  
320 influenced their behavior and their adherence or non-adherence to the rehabilitation program  
321 completion. However, given that health-related behavior is relatively difficult to operate in

322 human being [48] we do not foresee that these discussions over 6 sessions might have had a  
323 major impact on the results of the our study.

## 324 **CONCLUSION**

325 Sleep quantity and quality and psychological factors were not associated with time to meet the  
326 discharge criteria to return to sport following ACL-R. However, lower score of anxiety and  
327 insomnia prior to injury occurrence, sleep quality at 3m, 4.5m, 6m post-surgery and at the  
328 moment of meeting the discharge criteria to RTS were all associated with athletes' adherence to  
329 the rehabilitation program and RTS. Monitoring sleep quality and anxiety of athletes before and  
330 following ACL-R surgery is important to identify athletes who might have difficulties in  
331 adhering to completing rehabilitation programs to successfully RTS. Future studies should  
332 investigate the post- rehabilitation program period dynamics and successful RTS, and even return  
333 to performance.

## 334 **Practical Applications**

335 These results will hopefully help health care providers to monitor sleep quality and psychological  
336 factors of athletes before and following ACL-R surgery and to identify the patient-athletes at risk  
337 of poor adherence and difficulties to complete their rehabilitation program until meeting  
338 discharge criteria to RTS and to eventually put in place the appropriate strategies to support them.

## 339 **AUTHOR CONTRIBUTIONS**

340 All authors contributed in a complementary way to the design and implementation of the research,  
341 to the analysis of the results and to the writing of the manuscript.

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345 **Conflict of interests:**

346 The authors declared no conflict of interests regarding the publication of this manuscript.

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