

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 **Abstract**

2 This study explored the relation between athletes' sleep quality and imagery ability. A total
3 of 201 athletes (39.3% female, 60.7% male; $M_{\text{age}} = 23.28$ years, $SD = 6.00$) completed the
4 Sport Imagery Ability Questionnaire (SIAQ) and the Pittsburgh Sleep Quality Index (PSQI).
5 Simple regression analyses revealed that global sleep quality predicted affect imagery ability.
6 Multiple regression analyses revealed that daytime dysfunction predicted global imagery
7 ability as well as skill, strategy, affect, and mastery imagery ability dimensions. In addition,
8 use of sleeping medication predicted global imagery ability, as well as goal and affect
9 imagery ability dimensions. Results provide some support for Cumming and Williams'
10 (2012) revised applied model of deliberate imagery use, suggesting that individual factors
11 influence the effectiveness of imagery use. Specifically, athletes who have no disruption to
12 daily functioning due to sleep find it easier to image sport-related content.

13 *Key words:* athletes, sleep quality, imagery ability, revised applied model of
14 deliberate imagery use

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The Effects of Sleep Quality on Imagery Ability in Athletic Populations

1 **The Effects of Sleep Quality on Imagery Ability in Athletic Populations**
2 Imagery is possibly the most cited intervention method in sport psychology literature, with a
3 total of 245 academic papers in the last 5 years alone addressing this topic (search completed
4 on SportDiscus using search terms “imagery” AND “sport”, and limited to academic journals).
5 White and Hardy (1998) describe11 imagery as “an experience that mimics real experience.
6 We can be aware of “seeing” an image, feeling movements as an image, or experiencing the
7 real thing... It differs from dreams in that we are awake and conscious when we form an image”
8 (p. 389). In sport, imagery refers to the mental representation of sport relevant actions, and has
9 been associated with changes in cognitions, behaviors and thoughts in athletic populations
10 (Martin, Moritz, & Hall, 1999).

11 Over the past two decades, sport-based imagery research has focused on the five types
12 of imagery outlined in Paivio’s (1985) conceptual framework and the Sport Imagery
13 Questionnaire (Hall, Mack, Paivio & Hausenblas, 1998): (1) cognitive-specific (imagery of
14 specific sport skills), (2) cognitive general (imagery of strategies/tactical plays), (3)
15 motivational specific (imagery of specific goal orientated behaviors), (4) motivational general-
16 mastery (imagery of effective coping and mastery of challenging situations), and (5)
17 motivational general-arousal (imagery that represents feelings of relaxation, stress, arousal and
18 anxiety). Investigations into imagery practice and effectiveness have explored a plethora of
19 factors including the impact of sporting ability and experience (e.g., Gregg & Hall, 2006),
20 different theoretical approaches or modus operandi (e.g., Wright & Smith, 2009), and different
21 imagery types and their relationship to other psychological constructs (e.g., Cumming, Olphin,
22 & Law, 2007; Shearer, Thomson, Mellalieu, & Shearer, 2007). One of the most explored
23 factors in sport imagery literature is that of imagery ability (e.g., Gregg, Hall, McGowan, &
24 Hall, 2011; Wilson, Smith, Burden, & Holmes, 2010, Williams & Cumming, 2012), which can

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1 be defined as “an individual’s capability to form vivid, controllable images and retain them for
2 sufficient time to effect the desired imagery rehearsal” (Morris, Spittle, & Watt, 2005, p. 37).

3 In 2012, Cumming and Williams introduced the revised applied model of deliberate
4 imagery use, which extended from Martin, Moritz and Hall’s (1999) widely adopted original
5 model in four ways. First, the revised applied model acknowledges the importance of the
6 individual performing the imagery (who), placing particular emphasis on individual
7 characteristics that may influence imagery function and effectiveness. Second, the revised
8 applied model distinguishes between the type of imagery (what) and the function that it is used
9 for (why), suggesting that a specific imagery type can serve different functions depending on
10 the meaning associated with the imagery content. Third, the revised applied model clarifies
11 the role of imagery ability, outlining its impact on what and how an individual images, as well
12 as the outcomes associated with imagery use. Finally, the revised applied model accounts for
13 the diverse application of imagery, outlining how imagery interventions can be used across
14 domains such as dance, exercise, and rehabilitation in addition to sport.

15 Paivio (1986) outlined that all athletes have the capacity to image to some extent, but
16 that imagery ability will vary across individuals (i.e., a person may be more/less able to
17 generate imagery) and within individuals subject to the imagery content (i.e., a person may be
18 more able to generate cognitive versus motivational images). This is in keeping with the “who”
19 aspects outlined in Cumming and Williams’ (2012) model, which suggest that individual
20 factors such as age, gender, competitive level, and psychological traits and states will impact
21 upon imagery effectiveness (Cumming & Williams, 2013). Indeed, several factors are thought
22 to relate to imagery ability, including athletic experience (Abma, Fry, Li, & Relyea, 2002),
23 emotion regulation (Anuar, Cumming, & Williams, 2016), observation and movement priming
24 (Williams, Cumming, & Edwards, 2011), and corticospinal activation (Williams, Pearce,
25 Loporto, Morris, & Holmes, 2012). However, no consensus exists concerning the factors that

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1 might affect athletes' ability to generate effective images and to the best of our knowledge no
2 research has explored the impact of physiological factors associated with recovery status (e.g.,
3 sleep quality) upon imagery ability.

4 Sleep is an essential requirement for all basic human functions (Dattilo et al., 2011;
5 Meerlo, Sgoifo, & Suchecki, 2008) and is known to affect the autonomic nervous system,
6 endocrine system, and biochemical function when disrupted (e.g., Spiegel, Leproult, & Van
7 Cauter, 1999). From a psychological perspective, poor sleep also effects cognitive factors (e.g.,
8 Belenky et al., 2003) and mood states (e.g., Sinnerton & Reilly, 1992) and is therefore likely
9 to contribute to poor decision making and motivation to train (either physically or mentally).
10 Restricted sleep is a known problem in modern society (Meerlo et al., 2008), and also within
11 elite athlete populations (e.g., Leeder, Glaister, Pizzoferro, Dawson, & Pedlar, 2012). This
12 restriction is down to a combination of lifestyle (e.g., unsocial working hours), behavioral (e.g.,
13 poor sleep hygiene), and psychological factors (e.g., perceived stress level). In addition,
14 athletes specifically suffer disruptions as a direct function of their sporting activity. Research
15 demonstrates that training volume (Jürimäe, Mäestu, Purge, & Jürimäe, 2004), training times
16 (Sargent, Halson, & Roach, 2014), and competition all impact on athletes sleep quality
17 (Shearer, Jones, Kilduff, & Cook, 2015).

18 Sleep is reported to impact attention, working memory, long-term memory, motivation,
19 and visuo-motor performance, outlining its importance towards cognitive functioning (see
20 Alhola & Polo-Kantola, 2007 for a review). There is also consistent support, spanning
21 behavioral and neurophysiological studies, for the role of sleep in memory consolidation (see
22 Stickgold, 2005 for a review). The role of memory in the generation of mental imagery is well
23 explained from both a theoretical and empirical standpoint (Paivio 1985; Tong, 2013).
24 Therefore, the relationship that both sleep and imagery hold with memory indicates that sleep
25 will impact an individual's ability to generate imagery.

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1 9). The current competitive level of the participants ranged from amateur ($n = 183$) to
2 professional/international level athletes ($n = 18$). The study participants had been competing
3 in their respective sports for an average of 8.97 ± 6.29 years.

4 *Measures*

5 *Individual characteristics.* The study participants provided the research team with
6 information regarding their age, gender, primary sport, current competitive level, and years of
7 playing experience.

8 *Pittsburgh Sleep Quality Index.* The Pittsburgh Sleep Quality Index (PSQI; Buysse,
9 Reynolds, Monk, Berman, & Kupfer, 1989) was used to assess the perceived sleep quality of
10 the athlete participants. The PSQI comprises 19 items with 7 components related to sleep
11 habits over a one-month period prior to completion: subjective sleep quality (1 item), sleep
12 latency (2 items), sleep duration (1 item), habitual sleep efficiency (3 items), sleep disturbances
13 (9 items), use of sleeping medication (1 item), and daytime dysfunction (2 items). All
14 component scores are calculated using specific scoring instructions (see Buysse et al.), with
15 scores ranging from 0 (no difficulty) to 3 (severe difficulty) for each component. A global
16 score can also be calculated for the PSQI by combining the seven component scores, with a
17 range of 0 (no difficulty) to 21 (severe difficulty) for this global index. The PSQI has
18 demonstrated good internal reliability and test-retest reliability in clinical and non-clinical
19 settings (see Mollayeva et al., 2015 for a meta-analysis).

20 *Sport Imagery Ability Questionnaire.* The Sport Imagery Ability Questionnaire
21 (SIAQ; Williams & Cumming, 2011) was used to assess the ability of respondents to image
22 different types of imagery content. The questionnaire comprises 15 items with 5 subscales
23 related to different types of imagery ability: skill (3 items), strategy (3 items), goal (3 items),
24 affect (3 items), and mastery (3 items). Participants rated their ease of imaging for each item
25 using 7-point likert scale anchored by 1 (very hard to image) and 7 (very easy to image). The

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1 scale underwent extensive validation during initial design comprising of 1 exploratory factor
2 analysis, 2 progressive confirmatory factor analysis, and a final study examining the scales
3 construct validity alongside the Movement Imagery Questionnaire-3 (MIQ-3; Williams,
4 Cumming, Ntoumanis, Nordin-Bates, Ramsey, & Hall, 2012). In the final study, the scale
5 showed robust goodness of fit indices ($\chi^2(80) = 108.59, p < .05, CFI = .98, TLI = .97, SRMR$
6 $= .04, RMSEA = .04$) and satisfactory levels of composite reliability for all 5 subscales (.78-
7 .86). In this study, satisfactory Cronbach alpha scores were reported for the SIAQ (global =
8 .88), with questionable to good scores reported for the subscales of this measure (skill = .73,
9 strategy = .60, goal = .82, affect = .80, mastery = .68).

10 *Procedure*

11 Ethical approval was granted by the lead authors university ethics committee and all
12 participants provided informed consent prior to taking part in the study. An online survey pack
13 was developed using an online-survey provider (www.surveymonkey.com). The survey pack
14 contained a participant consent form, demographic questionnaire, PSQI, SIAQ, and participant
15 debrief form (presented in that order). Prior to involvement in the study, all participants were
16 notified that engagement with this study was voluntary, they had the right to withdraw at any
17 time during/after the study, and that the information provided would be treated confidentially
18 and stored securely on password-protected computers for all research team members. The
19 online questionnaire took approximately ten minutes to complete in full.

20 *Data Analyses*

21 All statistical procedures were conducted using a minimum significance level of $p = .05$. First,
22 data were screened for univariate normality, multivariate normality, and multicollinearity.
23 Second, regression analyses were run to explore the direction and relative contribution of sleep
24 quality towards variance in imagery ability. Specifically, simple regression analyses were used
25 to examine whether the global PSQI score predicted SIAQ scores (global, five subscales), and

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1 forced entry multiple regression analyses were used to examine whether the seven PSQI
2 component scores predicted SIAQ scores (global, five subscales).

3 **Results**

4 ***Data Screening***

5 For the final study sample, there were no missing values. Cook's distances were used to
6 examine the assumptions of multivariate normality, with a value greater than 1 indicative of
7 multivariate outliers (cf. Cook & Weisberg, 1982). For all regression analyses, Cook's
8 distance values were below 1 with a maximum value of 0.16 ($M = 0.01$, $SD = 0.01$),
9 indicating that no single case greatly influenced the respective models, leaving 201 cases for
10 each analysis. The variance inflation factor values were all below 10 with a maximum value
11 of 1.76 ($M = 1.31$, $SD = 0.23$) and the tolerance statistic scores were all above 0.20 with a
12 minimum value of 0.68 ($M = 0.78$, $SD = 0.12$), indicating no collinearity within the data.
13 Pearson's correlations were used to account for potential variance in sleep quality as a
14 function of 'years played' ($r = .08$) and 'highest level played' ($r = .03$) and indicated no
15 significant relationship between any of these variables ($p > .05$).

16 [INSERT TABLE 1 HERE]

17 ***Global Sleep Quality: Imagery Ability***

18 The relationship between global sleep quality and imagery ability was assessed using six
19 regression analyses. The first simple regression analysis identified that the global sleep
20 quality score accounted for 1.10% of variability in the global imagery ability score ($\beta = -.11$,
21 R^2 change = .01, $F_{1-199} = 2.29$, $p > .05$). Further simple regression analyses identified that the
22 global sleep quality score predicted affect imagery ability score, but not scores for the four
23 other imagery ability subscales. Specifically, global sleep quality score accounted for 0.30%
24 of variability in skill imagery ability ($\beta = -.05$, R^2 change = .01, $F_{1-199} = 0.59$, $p > .05$), 0.00%
25 of variability in strategy imagery ability ($\beta = -.00$, R^2 change = .00, $F_{1-199} = 0.00$, $p > .05$),

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1 0.80% of variability in goal imagery ability ($\beta = -.09$, R^2 change = .01, $F_{1-199} = 1.64$, $p > .05$),
2 2.70% of variability in affect imagery ability ($\beta = -.16$, R^2 change = .03, $F_{1-199} = 5.47$, $p <$
3 $.05$), and 0.60% of variability in mastery imagery ability ($\beta = -.08$, R^2 change = .01, $F_{1-199} =$
4 1.17 , $p > .05$).

5 *Components of Sleep Quality: Imagery Ability*

6 The relationship between the components of sleep quality and imagery ability was assessed
7 using six multiple regression analyses. The first multiple regression analysis reported that the
8 sleep quality components accounted for 14.00% of variability in global imagery ability.
9 Daytime dysfunction ($\beta = -.28$, R^2 change = .14, $F_{7-193} = 4.47$, $p < .001$) and use of sleeping
10 medication ($\beta = -.15$, R^2 change = .14, $F_{7-193} = 4.47$, $p < .05$) were identified as significant
11 predictors towards the global imagery ability score. All other sleep quality components were
12 not significant predictors of global imagery ability ($p > .05$).

13 [INSERT TABLE 2 HERE]

14 The second multiple regression analysis reported that the sleep quality components accounted
15 for 9.90% of variability in skill imagery ability. Daytime dysfunction ($\beta = -.23$, R^2 change =
16 $.10$, $F_{7-193} = 3.03$, $p < .01$) was identified as the only significant predictor towards the skill
17 imagery ability score. All other sleep quality components were not significant predictors of
18 skill imagery ability ($p > .05$).

19 [INSERT TABLE 3 HERE]

20 The third multiple regression analysis reported that the sleep quality components accounted
21 for 9.00% of variability in strategy imagery ability. Daytime dysfunction ($\beta = -.24$, R^2
22 change = .09, $F_{7-193} = 2.72$, $p < .01$) was identified as the only significant predictor towards
23 the strategy imagery ability score. All other sleep quality components were not significant
24 predictors of strategy imagery ability ($p > .05$).

25 [INSERT TABLE 4 HERE]

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1 The fourth multiple regression analysis reported that the sleep quality components accounted
2 for 8.30% of variability in goal imagery ability. Use of sleeping medication ($\beta = -.16$, R^2
3 change = .08, $F_{7-193} = 2.51$, $p < .05$) was identified as the only significant predictor towards
4 the goal imagery ability score. All other sleep quality components were not significant
5 predictors of goal imagery ability ($p > .05$).

6 [INSERT TABLE 5 HERE]

7 The fifth multiple regression analysis reported that the sleep quality components accounted
8 for 13.00% of variability in affect imagery ability. Daytime dysfunction ($\beta = -.21$, R^2 change
9 = .13, $F_{7-193} = 4.12$, $p < .01$) and use of sleeping medication ($\beta = -.26$, R^2 change = .13, F_{7-193}
10 = 4.12, $p < .001$) were identified as significant predictors towards the global imagery ability
11 score. All other sleep quality components were not significant predictors of goal imagery
12 ability ($p > .05$).

13 [INSERT TABLE 6 HERE]

14 The sixth multiple regression analysis reported that the sleep quality components accounted
15 for 10.80% of variability in mastery imagery ability. Daytime dysfunction ($\beta = -.33$, R^2
16 change = .11, $F_{7-193} = 3.32$, $p < .001$) was identified as the only significant predictor towards
17 the mastery imagery ability score. All other sleep quality components were not significant
18 predictors of mastery imagery ability ($p > .05$).

19 [INSERT TABLE 7 HERE]

20 **Discussion**

21 The aim of the current study was to examine the predictive capabilities of sleep quality
22 towards imagery ability in an athletic population. Specifically, we examined whether athlete
23 sleep quality predicted imagery ability in athletes. It was hypothesized that sleep quality
24 (global & seven components) would positively predict imagery ability (global & five types).
25 The study findings provide partial support of this hypothesis. Somewhat surprisingly, global

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1 sleep quality did not predict global imagery ability, and only held a predictive relationship
2 with affect imagery ability. This suggests that athletes who have higher overall quality of
3 sleep tend to be more able to generate imagery with content directed towards the positive
4 emotions associated with participation in sport (e.g., excitement, happiness). It is
5 consistently reported that sleep, and more specifically sleep deprivation, impacts negatively
6 upon a person's emotional states (e.g., Paterson et al., 2011), emotional regulation (e.g.,
7 Baum et al., 2014), perception of emotions (e.g., Daniela, Alessandro, Giuseppe, Fabio, &
8 Cristina, 2010), and ability to express emotions (Minkel, Htaik, Banks, & Dinges, 2011). In
9 combination, these findings suggest that if an athlete has a high quality of sleep they are
10 likely to be able to understand and express emotions more accurately. Given that affect
11 imagery involves the generation of images of positive emotions related to sport, it is
12 conceivable that sleep will impact upon an athlete's ability to generate this imagery type
13 through its relationship with emotion.

14 When exploring the predictive relationship between the seven components of sleep
15 quality and imagery ability, it was found that daytime dysfunction and use of sleeping
16 medication are the only two predictors of imagery ability types. Specifically, daytime
17 dysfunction predicted global, skill, strategy, affect, and mastery imagery ability, and use of
18 sleeping medication predicted global, goal, and affect imagery ability. It is surprising that
19 just two of seven sleep quality components predict imagery ability due to the apparent
20 relationship between sleep, mental imagery and memory. However, these findings may be
21 partially explained by the general sleep characteristics of the sample used in this study.
22 Leeder et al. (2012) report that sleep quality and quantity are worse for elite athletic
23 compared to non-athletic populations, whereas a study by Selby, Weinstein and Bird (1990)
24 found that 68% of student athletes reported that they got sufficient sleep for a maximum of
25 two nights per week. Based on these studies, it is understandable that on average our athlete

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1 cohort are diagnosed to have sleep disorder ($M = 6.05$) based on general population
2 guidelines (Buysse et al., 1989). This disordered sleeping is likely to be a long-term issue
3 which may be seen as ‘the norm’ for this population type. It is possible that the athletes in
4 this study do not believe their sleep duration or sleep quality to be ‘non-normal’ unless they
5 perceive it to impact upon their actual behavior (i.e., daytime functioning or use of
6 medication). Everyday functioning in sport incorporates both cognitive and physical tasks,
7 with athletes using all types of imagery fairly frequently within their sporting involvement
8 (e.g., Gregg, Hall, & Nederhof, 2005). The use of sleeping medication is said to impact
9 daytime functioning through cognitive and/or physical impairment (e.g., Verster,
10 Veldhuijzen, & Volkerts, 2004), outlining the impact that this can have upon subsequent
11 behavior, including the effective application of imagery.

12 The study findings lend partial support to Cumming and Williams’ (2012) adaptation
13 of the “who” component in the revised applied model of deliberate imagery use, whereby
14 greater importance is placed on the individual performing the imagery. A multitude of
15 individual characteristics are reported to influence imagery function, effectiveness, and the
16 outcomes associated with its use (Cumming & Williams, 2013). Our results show that global
17 sleep quality and specific components of sleep quality (daytime dysfunction, use of sleep
18 medication) impact upon different types of imagery ability in sport. It is possible that poor
19 sleep quality will reduce an athlete’s ability to recall memories, function cognitively, and
20 understand emotions, all important aspects of imagery development in sport. This finding
21 outlines the potential importance of physiological variables as a separate category of
22 individual differences for imagery use in sport, exercise, rehabilitation, and dance. All of
23 these domains require some form of physical and mental exertion, suggesting a need to better
24 understand the relationships between physiological states and imagery. Specifically, there is
25 a need to consider recovery-based indicators such as fatigue, hydration status, and

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1 injury/illness when applying imagery interventions and monitoring the outcomes associated
2 with imagery use.

3 This study undoubtedly has its merits, including the recruitment of a split-gender
4 sample of athletes from a wide variety of sports, and the extensive psychometric assessment
5 of sleep quality and imagery ability in sport. However, a number of limitations exist
6 surrounding the cross-sectional design and assessment methods used in this study. First, we
7 did not account for the influence of experimental demands on the results, whereby
8 participants may have guessed the study aims and answered questions accordingly. Similarly,
9 as the PSQI was presented to participants before the SIAQ, an acknowledgement of sleep
10 dysfunction might have biased answers to the SIAQ. Correlation analysis to examine the
11 relationship between participants' expectation about the study and the actual results would
12 have been useful to check this (see Holmes, Mathews, Mackintosh, & Dagleish, 2008).

13 Second, although our design allowed the research team to examine the relationship
14 between sleep quality and imagery ability across a relatively large sample of athletes, it does
15 not permit understanding of causality. In this respect, there is a need to explore the
16 interrelations between sleep and imagery in greater depth. For instance, research is warranted
17 examining whether interventions targeting better quality sleep also improve an athlete's
18 ability to image and his/her subsequent effectiveness of imagery use. One such intervention
19 that has been used with athletes is sleep extension, which involves the employment of a strict
20 sleep regime with a minimum sleep duration over an extended period of time (see e.g., Mah,
21 Mah, Kezirian, & Dement, 2011). Additionally, there is a need to consider the recursive
22 relationship that may exist between sleep and imagery ability by exploring the use of
23 imagery-based training methods such as layered stimulus response training to improve sleep
24 quality in athletic populations (see Cumming et al., 2016). The recommended study foci
25 should incorporate multi-modal assessment of both sleep quality and imagery ability as

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1 appropriate within the specific study designs. Alternative methods used to assess sleep
2 quality include sleep diaries and wrist activity monitors (e.g., Sargent, Lastella, Halson, &
3 Roach, 2014), whilst imagery ability has been measured objectively using physiological and
4 behavioral measures such as electroencephalography (Cremades & Pease, 2007), functional
5 magnetic resonance imaging (Cui, Jeter, Yang, Montague, & Eagleman, 2007), and
6 electromyography (Wilson et al., 2010).

7 In summary, this study extends the literature on the “who” component of Cumming
8 and Williams’ (2012) revised applied model of deliberate imagery use by exploring the
9 relationship between sleep quality and imagery ability in athletes. Data analyses revealed
10 that global sleep quality predicted affect imagery ability, and that two components of sleep
11 quality (daytime dysfunction and use of sleep medication) predicted global imagery ability
12 and various imagery ability types. The findings of this study suggest that different
13 physiological factors are associated with differences in sport imagery ability in athletic
14 populations, thus providing support for Cumming and Williams’ assertions that individual
15 characteristics warrant consideration when attempting to apply imagery affectively. Future
16 studies should explore the interrelations between sleep and imagery ability by attempting to
17 manipulate either variable and assessing the impacts upon both.

References

- 18
19 Abma, C. L., Fry, M. D., Li, Y., & Relyea, G. (2002). Differences in imagery content and
20 imagery ability between high and low confident track and field athletes. *Journal of*
21 *Applied Sport Psychology, 14*(2), 67-75. <http://dx.doi.org/10.1080/10413200252907743>
22 Alhola, P., & Polo-Kantola, P. (2007). Sleep deprivation: Impact on cognitive
23 performance. *Neuropsychiatric Disease and Treatment, 3*(5), 553-567.

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- 1 Anuar, N., Cumming, J., & Williams, S. (2016). Emotion regulation predicts imagery
2 ability. *Imagination, Cognition and Personality*, 36(3), 254-269.
3 <http://dx.doi.org/10.1177/0276236616662200>
- 4 Baum, K. T., Desai, A., Field, J., Miller, L. E., Rausch, J., & Beebe, D. W. (2014). Sleep
5 restriction worsens mood and emotion regulation in adolescents. *Journal of Child*
6 *Psychology and Psychiatry*, 55(2), 180-190. <http://dx.doi.org/10.1111/jcpp.12125>
- 7 Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P.,
8 ... & Balkin, T. J. (2003). Patterns of performance degradation and restoration during
9 sleep restriction and subsequent recovery: A sleep dose-response study. *Journal of Sleep*
10 *Research*, 12(1), 1-12. <http://dx.doi.org/10.1046/j.1365-2869.2003.00337.x>
- 11 Berlin, K. L., Means, M. K., & Edinger, J. D. (2010). Nightmare reduction in a Vietnam veteran
12 using imagery rehearsal therapy. *Journal of Clinical Sleep Medicine: JCSM: Official*
13 *Publication of the American Academy of Sleep Medicine*, 6(5), 487-488.
- 14 Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The
15 Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and
16 research. *Psychiatry research*, 28(2), 193-213. [http://dx.doi.org/10.1016/0165-](http://dx.doi.org/10.1016/0165-1781(89)90047-4)
17 [1781\(89\)90047-4](http://dx.doi.org/10.1016/0165-1781(89)90047-4)
- 18 Cook, R. D., & Weisberg, S. (1982). *Residuals and influence in regression*. New York:
19 Chapman and Hall.
- 20 Cremades, J., & Pease, D. (2007). Concurrent validity and reliability of lower and upper
21 alpha activities as measures of visual and kinaesthetic imagery ability. *The International*
22 *Journal of Sport and Exercise Psychology*, 5, 187-202.
23 <http://dx.doi.org/10.1080/1612197X.2007.9671819>

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

- 1 Cui, X., Jeter, C. B., Yang, D., Montague, P. R., & Eagleman, D. M. (2007). Vividness of
2 mental imagery: Individual variability can be measured objectively. *Vision*
3 *Research*, 47(4), 474-478. <https://doi.org/10.1016/j.visres.2006.11.013>
- 4 Cumming, J., Cooley, S. J., Anuar, N., Kosteli, M. C., Quinton, M. L., Weibull, F., &
5 Williams, S. E. (2016). Developing imagery ability effectively: A guide to layered
6 stimulus response training. *Journal of Sport Psychology in Action*, 1-11.
7 <http://dx.doi.org/10.1080/21520704.2016.1205698>
- 8 Cumming, J., Olphin, T., & Law, M. (2007). Self-reported psychological states and
9 physiological responses to different types of motivational general imagery. *Journal of*
10 *Sport and Exercise Psychology*, 29(5), 629-644. <https://doi.org/10.1123/jsep.29.5.629>
- 11 Cumming, J., & Williams, S.E. (2012). *The role of imagery in performance*. In S. Murphy (Ed),
12 *Handbook of sport and performance psychology* (p. 213–232). New York, NY: Oxford
13 University Press.
- 14 Cumming, J., & Williams, S. E. (2013). Introducing the revised applied model of deliberate
15 imagery use for sport, dance, exercise, and rehabilitation. *Movement & Sport Sciences*,
16 82(4), 69-81. <https://doi.org/10.1051/sm/2013098>
- 17 Daniela, T., Alessandro, C., Giuseppe, C., Fabio, M., & Cristina, M. (2010). Lack of sleep
18 affects the evaluation of emotional stimuli. *Brain Research Bulletin*, 82(1), 104-108.
19 <https://doi.org/10.1016/j.brainresbull.2010.01.014>
- 20 Dattilo, M., Antunes, H. K. M., Medeiros, A., Neto, M. M., Souza, H. S., Tufik, S., & De
21 Mello, M. T. (2011). Sleep and muscle recovery: Endocrinological and molecular basis
22 for a new and promising hypothesis. *Medical Hypotheses*, 77(2), 220-222.
23 <http://dx.doi.org/10.1016/j.mehy.2011.04.017>

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- 1 Debarnot, U., Creveaux, T., Collet, C., Doyon, J., & Guillot, A. (2009). Sleep contribution to
2 motor memory consolidation: A motor imagery study. *Sleep*, 32(12), 1559–1565.
- 3 Debarnot, U., Creveaux, T., Collet, C., Gemignani, A., Massarelli, R., Doyon, J., & Guillot,
4 A. (2009). Sleep-related improvements in motor learning following mental practice.
5 *Brain and Cognition*, 69(2), 398–405. <https://doi.org/10.1016/j.bandc.2008.08.029>
- 6 Gregg, M., & Hall, C. (2006). The relationship of skill level and age to the use of imagery by
7 golfers. *Journal of Applied Sport Psychology*, 18(4), 363–375.
8 <http://dx.doi.org/10.1080/10413200600944140>
- 9 Gregg, M., Hall, C., MCGowan, E., & Hall, N. (2011). The relationship between imagery
10 ability and imagery use among athletes. *Journal of Applied Sport Psychology*, 23(2),
11 129–141. <http://dx.doi.org/10.1080/10413200.2010.544279>
- 12 Gregg, M., Hall, C., & Nederhof, E. (2005). The imagery ability, imagery use, and
13 performance relationship. *The Sport Psychologist*, 19(1), 93-99.
14 <https://doi.org/10.1123/tsp.19.1.93>
- 15 Hall, C.R., Mack, D.E., Paivio, A., & Hausenblas, H.A. (1998). Imagery use by athletes:
16 Development of the Sport Imagery Questionnaire. *International Journal of Sport*
17 *Psychology*, 29, 73–89.
- 18 Harb, G. C., Thompson, R., Ross, R. J., & Cook, J. M. (2012). Combat-related PTSD
19 nightmares and imagery rehearsal: Nightmare characteristics and relation to treatment
20 outcome. *Journal of Traumatic Stress*, 25(5), 511-518.
21 <http://dx.doi.org/10.1002/jts.21748>
- 22 Holmes, E. A., Mathews, A., Mackintosh, B., & Dalgleish, T. (2008). The causal effect of
23 mental imagery on emotion assessed using picture-word cues. *Emotion*, 8(3),
24 395. <http://dx.doi.org/10.1037/1528-3542.8.3.395>

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

- 1 Jürimäe, J., Mäestu, J., Purge, P., & Jürimäe, T. (2004). Changes in stress and recovery after
2 heavy training in rowers. *Journal of Science and Medicine in Sport*, 7(3), 335-339.
3 [https://doi.org/10.1016/S1440-2440\(04\)80028-8](https://doi.org/10.1016/S1440-2440(04)80028-8)
- 4 Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012). Sleep duration and
5 quality in elite athletes measured using wristwatch actigraphy. *Journal of Sports*
6 *Sciences*, 30(6), 541-545. <http://dx.doi.org/10.1080/02640414.2012.660188>
- 7 Mah, C. D., Mah, K. E., Kezirian, E. J., & Dement, W. C. (2011). The effects of sleep
8 extension on the athletic performance of collegiate basketball players. *Sleep*, 34(7), 943-
9 950. <http://dx.doi.org/10.5665/sleep.1132>
- 10 Martin, K. A., Moritz, S. E., & Hall, C. R. (1999). Imagery use in sport: A literature review
11 and applied model. *The Sport Psychologist*, 13, 245–268.
12 <https://doi.org/10.1123/tsp.13.3.245>
- 13 Meerlo, P., Sgoifo, A., & Suchecki, D. (2008). Restricted and disrupted sleep: Effects on
14 autonomic function, neuroendocrine stress systems and stress responsivity. *Sleep*
15 *Medicine Reviews*, 12(3), 197-210. <http://dx.doi.org/10.1016/j.smr.2007.07.007>
- 16 Minkel, J., Htaik, O., Banks, S., & Dinges, D. (2011). Emotional expressiveness in sleep-
17 deprived healthy adults. *Behavioral Sleep Medicine*, 9(1), 5-14.
18 <http://dx.doi.org/10.1080/15402002.2011.533987>
- 19 Mollayeva, T., Thurairajah, P., Burton, K., Mollayeva, S., Shapiro, C. M., & Colantonio, A.
20 (2016). The Pittsburgh sleep quality index as a screening tool for sleep dysfunction in
21 clinical and non-clinical samples: A systematic review and meta-analysis. *Sleep*
22 *Medicine Reviews*, 25, 52-73. <http://dx.doi.org/10.1016/j.smr.2015.01.009>
- 23 Morris, T., Spittle, M., & Watt, A. P. (2005). *Imagery in sport*. Human Kinetics.
- 24 Paivio, A. (1985). Cognitive and motivational functions of imagery in human performance.
25 *Canadian Journal of Applied Sport Science*, 10, 22S–28S.

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

- 1 Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford
2 University Press.
- 3 Paterson, J.L., Dorrian, J., Ferguson, S.A., Jay, S.M., Lamond, N., Murphy, P.J., Campbell,
4 S.S., & Dawson, D. (2011). Changes in structural aspects of mood during 39–66 h of sleep
5 loss using matched controls. *Applied Ergonomics*, 42, 196–201.
6 <https://doi.org/10.1016/j.apergo.2010.06.014>
- 7 Roberts, R., Callow, N., Hardy, L., Markland, D., & Bringer, J. (2008). Movement imagery
8 ability: Development and assessment of a revised version of the vividness of movement
9 imagery questionnaire. *Journal of Sport and Exercise Psychology*, 30(2), 200–221.
10 <https://doi.org/10.1123/jsep.30.2.200>
- 11 Sargent, C., Halson, S., & Roach, G. D. (2014). Sleep or swim? Early-morning training
12 severely restricts the amount of sleep obtained by elite swimmers. *European Journal of*
13 *Sport Science*, 14, S310-S315. <http://dx.doi.org/10.1080/17461391.2012.696711>
- 14 Sargent, C., Lastella, M., Halson, S., & Roach, G. (2014). The impact of training schedules on
15 the sleep and fatigue of elite athletes. *Chronobiology International*, 31(10), 1160–1168.
16 <http://dx.doi.org/10.3109/07420528.2014.957306>
- 17 Selby, R., Weinstein, H. M., & Bird, T. S. (1990). The health of university athletes: Attitudes,
18 behaviors, and stressors. *Journal of American College Health*, 39(1), 11-18.
19 <http://dx.doi.org/10.1080/07448481.1990.9936208>
- 20 Shearer, D. A., Jones, R. M., Kilduff, L. P., & Cook, C. J. (2015). Effects of competition on
21 the sleep patterns of elite rugby union players. *European Journal of Sport Science*, 15(8),
22 681-686. <http://dx.doi.org/10.1080/17461391.2015.1053419>
- 23 Shearer, D. A., Thomson, R., Mellalieu, S. D., & Shearer, C. R. (2007). The relationship
24 between imagery type and collective efficacy in elite and non-elite athletes. *Journal of*
25 *Sports Science & Medicine*, 6(2), 180–187.

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

- 1 Sinnerton, S., & Reilly, T. (1992). Effects of sleep loss and time of day in
2 swimmers. *Biomechanics and Medicine in Swimming: Swimming Science*, 4, 399-404.
- 3 Spiegel, K., Leproult, R., & Van Cauter, E. (1999). Impact of sleep debt on metabolic and
4 endocrine function. *The Lancet*, 354(9188), 1435-
5 1439. [http://dx.doi.org/10.1016/S0140-6736\(99\)01376-8](http://dx.doi.org/10.1016/S0140-6736(99)01376-8)
- 6 Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature*, 437(7063), 1272-1278.
7 <http://dx.doi.org/10.1038/nature04286>
- 8 Tong, F. (2013). Imagery and visual working memory: One and the same? *Trends in Cognitive*
9 *Sciences*, 17(10), 489-490. <http://dx.doi.org/10.1016/j.tics.2013.08.005>
- 10 Verster, J. C., Veldhuijzen, D. S., & Volkerts, E. R. (2004). Residual effects of sleep
11 medication on driving ability. *Sleep Medicine Reviews*, 8(4), 309-325.
12 <https://doi.org/10.1016/j.smrv.2004.02.001>
- 13 White, A., & Hardy, L. (1998). An in-depth analysis of the uses of imagery by high-level
14 slalom canoeists and artistic gymnastics. *The Sport Psychologist*, 12, 387-403.
15 <https://doi.org/10.1123/tsp.12.4.387>
- 16 Williams, S. E., & Cumming, J. (2011). Measuring athlete imagery ability: the sport imagery
17 ability questionnaire. *Journal of Sport and Exercise Psychology*, 33(3), 416-440.
18 <https://doi.org/10.1123/jsep.33.3.416>
- 19 Williams, S. E., & Cumming, J. (2012). Sport imagery ability predicts trait confidence, and
20 challenge and threat appraisal tendencies. *European Journal of Sport Science*, 12(6), 499-
21 508. <http://dx.doi.org/10.1080/17461391.2011.630102>
- 22 Williams, S. E., Cumming, J., & Edwards, M. G. (2011). The functional equivalence between
23 movement imagery, observation, and execution influences imagery ability. *Research*
24 *Quarterly for Exercise & Sport*, 82(3), 555-564.
25 <http://dx.doi.org/10.1080/02701367.2011.10599788>

SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

- 1 Williams, S. E., Cumming, J., Ntoumanis, N., Nordin-Bates, S. M., Ramsey, R., & Hall, C.
2 (2012). Further validation and development of the Movement Imagery Questionnaire.
3 *Journal of Sport and Exercise Psychology*, 34(5), 621–646.
4 <https://doi.org/10.1123/jsep.34.5.621>
- 5 Williams, J., Pearce, A. J., Loporto, M., Morris, T., & Holmes, P. S. (2012). The relationship
6 between corticospinal excitability during motor imagery and motor imagery ability.
7 *Behavioural Brain Research*, 226(2), 369–375.
8 <https://doi.org/10.1016/j.bbr.2011.09.014>
- 9 Wilson, C., Smith, D., Burden, A., & Holmes, P. (2010). Participant-generated imagery scripts
10 produce greater EMG activity and imagery ability. *European Journal of Sport Science*,
11 10(6), 417–425.
- 12 Wright, C. J., & Smith, D. (2009). The effect of PETTLEP imagery on strength performance.
13 *International Journal of Sport and Exercise Psychology*, 7(1), 18–31.
14 <http://dx.doi.org/10.1080/1612197X.2009.9671890>

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 1

2 *Mean and standard deviation values for sleep quality and sport imagery ability scores*

	M	SD
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Pittsburgh Sleep Quality Index		
Subjective Sleep Quality	1.13	0.75
Sleep Latency	1.44	0.90
Sleep Duration	0.40	0.72
Habitual Sleep Efficiency	0.45	0.82
Sleep Disturbances	1.35	0.52
Use of Sleeping Medication	0.15	0.57
Daytime Dysfunction	1.13	0.72
Global Sleep Quality	6.05	2.90
Sport Imagery Ability Questionnaire		
Skill Imagery Ability	4.42	0.90
Strategy Imagery Ability	4.23	0.87
Goal Imagery Ability	4.07	1.26
Affect Imagery Ability	4.84	1.02
Mastery Imagery Ability	4.15	0.97
Global Imagery Ability	4.34	0.76
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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 2

2 *Summary of multiple regression analysis for sleep quality components predicting global*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	4.70	0.16	
Subjective Sleep Quality	0.06	0.09	.06
Sleep Latency	0.10	0.06	.11
Sleep Duration	-0.04	0.09	-.04
Habitual Sleep Efficiency	0.11	0.07	.12
Sleep Disturbances	-0.16	0.11	-.11
Use of Sleeping Medication	-0.20	0.09	-.15*
Daytime Dysfunction	-0.30	0.08	-.28***

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.14, Adjusted R²= 0.11, F₇₋₁₉₃=4.47, (* p < 0.05, *** p <*

6 *0.001).*

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 3

2 *Summary of multiple regression analysis for sleep quality components predicting skill*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	4.64	0.19	
Subjective Sleep Quality	0.04	0.11	.03
Sleep Latency	0.14	0.07	.14
Sleep Duration	-0.12	0.10	-.09
Habitual Sleep Efficiency	0.16	0.09	.15
Sleep Disturbances	-0.10	0.13	-.06
Use of Sleeping Medication	-0.13	0.11	-.09
Daytime Dysfunction	-0.29	0.10	-.23**

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.10, Adjusted R²= 0.07, F₇₋₁₉₃=3.03, (** p < 0.01).*

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 4

2 *Summary of multiple regression analysis for sleep quality components predicting strategy*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	4.50	0.19	
Subjective Sleep Quality	0.12	0.11	.11
Sleep Latency	0.10	0.07	.10
Sleep Duration	0.05	0.10	.04
Habitual Sleep Efficiency	0.08	0.08	.07
Sleep Disturbances	-0.19	0.13	-.11
Use of Sleeping Medication	-0.11	0.11	-.07
Daytime Dysfunction	-0.29	0.09	-.24**

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.09, Adjusted R²= 0.06, F₇₋₁₉₃=2.72, (** p < 0.01).*

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 5

2 *Summary of multiple regression analysis for sleep quality components predicting goal*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	4.60	0.27	
Subjective Sleep Quality	-0.07	0.15	-.04
Sleep Latency	0.12	0.10	.09
Sleep Duration	-0.03	0.15	-.01
Habitual Sleep Efficiency	0.19	0.12	.12
Sleep Disturbances	-0.33	0.18	-.14
Use of Sleeping Medication	-0.35	0.16	-.16*
Daytime Dysfunction	-0.18	0.14	-.10

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.08, Adjusted R²= 0.05, F₇₋₁₉₃=2.51, (** p < 0.01).*

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 6

2 *Summary of multiple regression analysis for sleep quality components predicting affect*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	5.21	0.21	
Subjective Sleep Quality	-0.00	0.12	-.00
Sleep Latency	0.09	0.08	.08
Sleep Duration	-0.06	0.12	-.04
Habitual Sleep Efficiency	0.08	0.09	.06
Sleep Disturbances	-0.08	0.14	-.04
Use of Sleeping Medication	-0.46	0.12	-.26***
Daytime Dysfunction	-0.30	0.11	-.21**

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.13, Adjusted R²= 0.10, F₇₋₁₉₃=4.12, (** p < 0.01, *** p <*

6 *.001).*

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SLEEP QUALITY AND IMAGERY ABILITY IN ATHLETES

1 Table 7

2 *Summary of multiple regression analysis for sleep quality components predicting mastery*

3 *imagery ability score in athletes*

	<i>B</i>	<i>B_{SE}</i>	<i>β</i>
Constant	4.55	0.21	
Subjective Sleep Quality	0.19	0.12	.15
Sleep Latency	0.03	0.08	.03
Sleep Duration	-0.05	0.11	-.04
Habitual Sleep Efficiency	0.05	0.09	.04
Sleep Disturbances	-0.12	0.14	-.07
Use of Sleeping Medication	0.05	0.12	-.03
Daytime Dysfunction	-0.45	0.10	-.33***

4 *Note: B = Unstandardised Beta Coefficient, B_{SE} = Standard Error of B, β = Standardised*

5 *Beta Coefficient. N = 201, R²=0.11, Adjusted R²= 0.08, F₇₋₁₉₃=3.32, (***) p < .001).*

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