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Napping improves afternoon power and perceptual measures in elite rugby union athletes.

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AUTHORS:

Angus Teece^{1,2}, Martyn Beaven¹, Christos K. Argus², Nicholas Gill^{1,3}, Matthew W. Driller⁴

¹ Te Huataki Waiora School of Health, University of Waikato, Hamilton, New Zealand.

² Chiefs Rugby Club, Hamilton, New Zealand.

³ New Zealand Rugby, Wellington, New Zealand

⁴ Sport and Exercise Science, School of Allied Health, Human Services and Sport, La Trobe University, Melbourne, Australia.

Corresponding Author:

Angus Teece,
University of Waikato, Gate one, Knighton Rd, Hillcrest, Hamilton, New Zealand.
angus.teece@gmail.com. +64 22 018 8640

ABSTRACT

Daytime napping is a strategy commonly used by elite athletes in both training and match-day settings. However, whilst the use of napping appears to be widespread in athletes, there is currently limited interventional studies on the efficacy of napping on physical performance in elite team-sport athletes. Therefore, this study aimed to investigate the impact of a daytime nap (<1 h) on afternoon performance in a cohort of professional rugby union athletes. In a randomized, crossover design, 15 athletes (mean \pm SD, age: 21 ± 2 years) performed a nap (NAP) and no-nap (CON) condition on two occasions separated by one week. Athletes completed baseline testing of choice reaction time, subjective wellness, and a 6-s peak power test on a cycle ergometer in the morning, followed by 2 x 45-minute training sessions, after which athletes either completed the NAP or CON condition at 1200h. One hour following the nap period, baseline measures were retested in addition to a 30-minute fixed-intensity interval cycle and a 4-minute maximal effort cycling test. A significant group x time interaction was determined for 6-s peak power output (+116.8 W, $p < 0.01$, $d = 0.55$), perceived fatigue (-0.2 AU, $p = 0.01$, $d = 0.37$) and muscle soreness (-0.1 AU, $p = 0.04$, $d = 0.75$) in favor of the NAP condition. A significantly lower rating of perceived exertion (-1.2 AU, $p < 0.01$, $d = 1.72$) was recorded for the fixed-intensity session in favor of NAP. This study highlights that utilizing daytime naps between training sessions on the same day can improve afternoon peak power as well as lower perceptions of fatigue, soreness, and exertion during afternoon training sessions in professional rugby union athletes.

INTRODUCTION

Numerous factors, including training and competition schedules, frequent travel, use of ergogenic aids, unfamiliar sleeping environments and high training loads, have been suggested to impair sleep in athlete populations (Walsh *et al.*, 2020). Insufficient sleep duration has been demonstrated to impact performance, causing decrements in physical performance (Kirschen, Jones and Hale, 2018), negatively affecting mood (Sargent *et al.*, 2014), and decreasing cognitive function (Taheri and Arabameri, 2012). Therefore, strategies that can increase total daily sleep may allow for the maintenance of training loads. Indeed, extending night-time sleep has been shown to increase performance, support optimal hormonal responses and adaptation in 25 professional rugby union athletes (Swinbourne *et al.*, 2018). However, exploring alternative methods to increase total daily sleep is necessary when night-time sleep cannot be extended due to scheduling constraints. One such method previously used to extend the total daily sleep duration is the use of daytime napping.

Napping has been defined as a period of sleep less than 50% of an individual's average nocturnal sleep duration (Dinges *et al.*, 2017). The use of napping in elite athlete populations has been widespread (Lastella *et al.*, 2021), with daytime naps reported to be commonly used in team sport athletes. In support of this suggestion, Thornton *et al.* (2017) previously reported that across a 2-week preseason period, 156 naps were taken within a cohort of 31 professional rugby league athletes in both home and away environments. Previous work from our laboratory (Teece *et al.* 2022) highlighted that 86% of professional

rugby union athletes reported napping on match-day throughout a season. In the same study, we also found that athletes cited increasing alertness, energy, and performance as the most common reasons for using daytime naps (Teece *et al.*, 2022).

Given the widespread use of napping as a strategy in rugby union athletes, it seems that this is a population that may be suffering from sleep debt. Supporting this suggestion, Dunican and colleagues (2018) previously reported that professional rugby union athletes obtain an average of 6 h 30 min of sleep per night, which is below the recommended amount of sleep suggested in the general population of 7-9 hours (Watson *et al.*, 2015). A lack of sleep in rugby union athletes has been shown to result in symptoms of excessive daytime sleepiness (Dunican *et al.*, 2018) which has been reported to decrease performance in athlete populations (Fullagar *et al.*, 2015). Extending night-time sleep may not be possible for professional rugby union athletes because of early training (Dunican *et al.*, 2019), playing schedules, and travel requirements (Smithies *et al.*, 2021) and therefore, daytime naps may be a reason for their prevalence in this population.

Daytime naps have been most commonly reported to occur in the midafternoon (13:00-16:00h), coinciding with a natural dip in circadian rhythms (Botonis, Koutouvakis and Toubekis, 2021) which has been suggested to affect cognitive (Milner and Cote, 2009) and physical performance (Lastella *et al.*, 2021). Daaloul and colleagues (2019) investigated the effects of daytime napping in elite-level Karate athletes, with athletes performing a 30-minute post-lunch nap or post-lunch rest period (no nap) at 13:00 following either a full night's sleep (>7h) or a night of partial sleep deprivation (4h). The findings highlighted that

a 30-minute nap enhanced cognitive outcomes when following either a full night of sleep or a night of partial sleep deprivation. Furthermore, it was reported that the short nap had a positive effect on physical and cognitive deteriorations in performance caused by either sleep loss or by fatigue-induced training. Similarly, O'Donnell et al. (2018) revealed that a nap of less than 20-minutes enhanced neuromuscular performance. Improvements in countermovement jump peak velocity were observed in favour of the 20-minute nap compared to no nap or a nap longer than 20-minutes in elite netball athletes.

Whilst daytime napping is commonly used amongst team sport athletes, there is currently a paucity of experimental research investigating the effects of daytime naps following morning training on subsequent performance in elite team-sport athletes. Therefore, this study aimed to examine the impact of a 1-hour daytime nap on afternoon performance of peak power, reaction time, subjective wellness, and aerobic performance in a cohort of professional rugby union athletes.

METHODS

Participants

A sample of 15 professional rugby players who were in their competition season and competed in the Super Rugby competition (mean \pm SD age: 21 ± 2 years, body mass: 105.7 ± 11.6 kg, height: 186.8 ± 5.4 cm) volunteered to participate in the current study. Participants were required to be illness and injury-free at the time of data collection to partake in the study. Additionally, all participants needed to be able to undertake both conditions of the study within two weeks to be eligible to participate. Before the commencement of data collection, participants provided informed consent, and the university human research ethics committee granted ethics approval (HREC 2019#17).

Research Design

The research design is described in Figure 1. A familiarization trial took place prior to the first day of data collection, and all participants were made familiar with all tests and surveys performed. The day before data collection, athletes were provided with a wrist actigraph (ReadiBand, Fatigue Science, Vancouver, BC, Canada.) which they were required to wear the night before data collection to collect sleep measures. On data collection days, athletes were required to undertake baseline measures (subjective wellness, choice reaction time, and 6-second peak power) followed by two typical training activities (resistance training and running conditioning: see below for details) of 45-minute duration. Morning training was followed by an hour period in which participants were to have lunch, athletes were prohibited from having caffeine or any other stimulants. At 1200h, athletes were randomly assigned to either nap (NAP) or no-nap (CON) conditions. A 30-minute period separated

the NAP and CON from afternoon tests, which included a warm-up consisting of 10 minutes of self-selected intensity cycling and dynamic stretching (hamstrings and quadriceps, hip flexors and extensors, calf, and ankle mobility). This 30-minute period post-nap before afternoon testing was included to allow for and minimize sleep inertia based on previous research (Lastella *et al.*, 2021). Afternoon testing started with retesting of baseline measures and then consisted of a 30-minute fixed-intensity interval session and a 4-minute maximal effort time trial.











<p>09:00</p> <p>Baseline Measures</p>  Wellness assessment  Choice Reaction Time  6s Peak Power	<p>09:30</p> <p>Morning Training</p>  Resistance Training  Running Conditioning	<p>11:00</p> <p>Lunch</p>	<p>12:00</p> <p>NAP</p>	<p>13:00</p> <p>30 min Prep</p>	<p>13:30</p> <p>Baseline Measures - Retest</p>  Wellness assessment  Choice Reaction Time  6s Peak Power	<p>14:00</p> <p>Afternoon Performance</p>  Fixed Interval Session  4min Time Trial
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Figure 1. Experimental Protocol.

Nap trial (NAP)

The nap trial involved participants attending a dedicated sleep room for a period of 1-hour at 1200h. The room was dark and temperature-controlled at 18 °C, participants were provided with eye masks, earplugs, and beds in which to sleep. Participants were not allowed to bring phones or other technology (e.g., smartwatches) into the sleep room. Participants were required to stay in the sleep room for the entire hour period and were

required to relax in the sleep room for the hour if they could not get to sleep. Following the 1-hour nap period, participants were asked if they napped (yes or no) and were to report their self-estimated nap duration. During the same 1-hour period, the CON condition was instructed not to sleep and not to consume caffeine or any other stimulants; otherwise, they were allowed to do as they usually would between morning and afternoon training sessions, including having access to phones and other technology such as games and music in the team lounge,

Sleep Monitoring

Quantitative sleep measures were collected the night before data collection to ensure sleep the night before each testing day was similar. Sleep measures were collected via wrist actigraphy (ReadiBand, Fatigue Science, Vancouver, BC, Canada). Participants were required to wear the wrist actigraph on either wrist the night before data collection (Driller, O'Donnell, & Tavares, 2017), and participants were asked to maintain their regular sleep routine. At the beginning of each data collection day, the data was wirelessly downloaded to an iPad and then analyzed using the manufacturer's online software. The raw activity data was translated into sleep-wake indices, including total sleep time (TST), sleep efficiency (SE%), and sleep latency (SL). The Readiband has been validated against polysomnography (PSG) and has been deemed to be acceptable with approximately 90% agreement in total sleep duration compared to PSG (Dunican, Murray, *et al.*, 2018). Furthermore, the inter-device reliability of the Readiband has shown to have high levels of agreement (Driller, McQuillan, & O'Donnell, 2016).

Subjective wellness

A wellness questionnaire based on the previous work of Hooper and Mackinnon (1995) was completed in the morning and afternoon for both nap and CON conditions. The questionnaire comprised of three questions related to fatigue, general muscle soreness, and alertness which were all rated on a scale of 1-7 Likert-type scale where 1 represented a good/desirable score (e.g., very fresh) and 7 represented a poor score (e.g. very fatigued).

Reaction Time Test

Measures of reaction time were collected at two time points (morning and afternoon) for each trial. Reaction time was assessed via a choice reaction time test conducted using the Psych lab 101 application for iPad (Neurobehavioral Systems, San Francisco, USA). The use of mobile devices to assess choice reaction time has been shown to be a valid and reliable way of assessing choice reaction, as described by Burke et al. (Burke *et al.*, 2017). The choice reaction test required participants to react to two different stimuli as quickly as possible and touch the corresponding side of the screen. If the participants saw a red box, they were required to touch the left-hand side of the screen as quickly as possible. If they saw a blue box appear, they were required to touch the right-hand side of the screen. The participants were required to complete the test, which consisted of 40 trials of each stimulus. The choice reaction test took approximately 3 minutes in total to complete. At the completion of the test average reaction time was recorded by the research team for analysis.

Peak Power Assessment

Peak power was assessed in the morning and afternoon of both conditions using the 6-second peak power test on a Wattbike cycle ergometer (Wattbike Ltd, Nottingham, UK). The 6-second peak power test was performed as an assessment of lower-body neuromuscular power. On the initial trial, saddle and handlebar height positions were set up according to athletes' preferences and were replicated thereafter. Resistance settings for the test were determined according to the recommendations by the Wattbike software based on the athlete's body mass. The 6-second peak power test was initiated following a 5-second countdown which was followed by a verbal command of "Go". The test employed a seated stationary start with the participants self-selecting the leg which initiated the first downstroke. Participants were instructed to remain in a seated position and produce maximal effort for the 6-second duration. The completion of the test was indicated via another verbal command of "Stop" from the researcher. Peak and relative peak power (W and $W \cdot kg^{-1}$) were recorded for analysis. The test-retest reliability of the 6-second peak power assessment has previously been reported by Wehbe et al. (2015), who reported an ICC of 0.96 and CV of 3.0%.

Resistance Training

Participants completed a resistance training program which was designed by the team's strength and conditioning staff. The program was designed to increase maximal strength and power, including 3 upper body and 3 lower body exercises. The resistance program took approximately 45 minutes to complete, and the same resistance training session was completed for both conditions. At the completion of the resistance training session, participants were required to report a rating of perceived effort (RPE). Borg's modified 1-

10 scale (Borg 1982) was used to assess each participant's perception of exertion from each training session.

Conditioning Session

Participants were required to undertake a running conditioning session designed by the team's strength and conditioning coaches. The session had components of repeated speed, maximal aerobic speed and high-intensity interval running. The running conditioning session took approximately 45 minutes to complete, and the same session was completed on the same standard-sized rugby union field on both occasions. For each session, locomotion activity was measured using an 18 Hz GPS unit to ensure trials were the same each week (Apex Pro Series Pod, STATSports, Belfast, UK). Units were worn on the upper back to decrease variability, and each participant used the same GPS unit for both conditions. Heart rate (HR) monitors (Polar Electro Oy, Kempele, Finland) were worn by all participants, with average and maximal heart rate recorded by researchers for analysis. Finally, each participant reported a rating of perceived exertion after the conditioning session. RPE was assessed using Borg's modified 1-10 scale.

Fixed-intensity interval cycling test

Participants undertook a fixed interval cycling test in the afternoon on a Wattbike ergometer on both occasions. The fixed intensity session was included in the experimental design to ensure that fatigue levels were similar before the 4-min time trial while also assessing the physiological and perceptual responses to fixed exercise following the NAP and CON trials. Participants were required to complete a 30-minute interval session which

consisted of a 2-minute intensity interval at $2.5 \text{ W}\cdot\text{kg}^{-1}$ immediately followed by a 3-minute recovery interval at $1.5 \text{ W}\cdot\text{kg}^{-1}$. Participants completed both intensity and recovery intervals 6 times in total. Resistance settings were self-selected by the participants to maintain the prescribed power outputs. Participants wore HR monitors with average and maximal HR collected for analysis. Additionally, average power output (W) and RPE were collected at the completion of the test and were used for analysis.

4-minute Time Trial (4-min TT)

A 4-minute time trial was performed on a Wattbike cycle ergometer on both occasions to assess afternoon maximal aerobic performance. Participants self-selected their resistance settings before the commencement of the time trial. The time trial commenced from a stationary start with athletes selecting the foot which initiated the first downwards stroke. The time trial began following a 5-second count down followed by a verbal confirmation of “Go”. Participants were instructed to perform maximally throughout the 4-minute test. Throughout the test, participants were given verbal encouragement and indicators of time remaining however, participants were blinded from all performance outcomes. Heart rate was consistently monitored throughout the 4-min period, with average and maximal heart rate recorded at the 4-minute mark for analysis. The 4-minute time trial has shown to have strong inter-day reliability, with Driller et al. (2014) reporting an ICC of 0.94, a TEM of 8.8 Watts and a CV of 2.3%.

Statistical Analyses

All descriptive statistics are reported as means \pm standard deviation unless otherwise stated. Statistical analysis was performed using the Statistical Package for Social Sciences (V.27.0, SPSS Inc., Chicago, IL, USA), with statistical significance set at $p < 0.05$ for all analyses. A two-way repeated-measures ANOVA, with 2 (condition: NAP, CON) \times 2 (time: PRE, POST) factors, was performed to determine the differences in wellness assessments, reaction time, and peak power. Analysis of the studentized residuals showed normality, as assessed by the Shapiro-Wilk test of normality and no outliers were present, as assessed by no studentized residuals greater than ± 3 standard deviations. The main effects were run to identify where statistically significant differences existed. Additionally, paired-sample t-tests were used to compare HR and RPE in the fixed intensity cycling test, power output in the 4-minute time trial, sleep indices, GPS, and heart rate data between the NAP and CON for morning training. Effect-size statistics were calculated using Cohen's d and interpreted using thresholds of 0.2, 0.5, and 0.8 for *small*, *moderate*, and *large*, respectively (Cohen, 1988). An effect size of <0.2 was considered *trivial*, and the effect was deemed *unclear* if the 95% confidence interval overlapped the thresholds for both *small* ($d = 0.2$) positive and negative effects.

RESULTS

Analysis of sleep indices the night before each trial (CON and NAP) revealed no differences ($p > 0.05$) between conditions for any sleep measures, including total sleep time, sleep efficiency, and sleep latency (Table 1). When morning training data was analyzed, the morning resistance training elicited similar RPE's (5.3 ± 0.8 vs. 5.3 ± 0.7 , $p = 1.0$) for the CON and NAP conditions. Additionally, the running conditioning elicited a similar running distance (3019 ± 56 m vs. 3037 ± 80 m, $p = 0.58$), mean HR (156 ± 7 beats·min⁻¹ vs. 154 ± 6 beats·min⁻¹, $p = 0.10$) and RPE (8.3 ± 0.6 vs. 8.3 ± 0.7 , $p = 1.00$) for CON and NAP conditions indicating that the morning exercise was completed at a similar physical intensity for each trial. Analysis of participants' responses to the 1-hour nap period revealed all athletes reported being able to successfully nap, with an average self-perceived nap duration of 35 ± 10 minutes.

Table 1. Data (mean \pm SD) for comparison of total sleep time, sleep efficiency and sleep latency as assessed via wrist actigraphy between the NAP and CON conditions from the night before data collection, including p -values and effects size comparison between conditions

Measure	Condition	Mean \pm SD	p -Value	ES (d) \pm 90% CI
Total Sleep Time (h:mm)	NAP	7:25 \pm 0:41	0.95	0.03 \pm 0.89, <i>unclear</i>
	CON	7:23 \pm 0:44		
Sleep Efficiency (%)	NAP	90.0 \pm 3.2	0.73	0.20 \pm 1.04, <i>unclear</i>
	CON	89.1 \pm 3.8		
Sleep Latency (min)	NAP	11.1 \pm 4.0	0.92	0.06 \pm 1.13, <i>unclear</i>
	CON	10.8 \pm 3.9		

Peak Power

Results from the 2-way repeated measure ANOVA revealed a statistically significant group x time interaction for absolute peak power, $F(1,14) = 21.46, p < 0.01$ (Figure 2) and relative peak power, $F(1,14) = 24.04, p < 0.01$. The NAP condition was associated with improvements in absolute and relative peak power (Table 2). *Post-hoc* testing showed that the POST time point was significantly higher absolute peak power ($p < 0.01$), a mean difference of 115.4 (W) and relative peak power ($p < 0.01$), a mean difference of 1.1 ($\text{W} \cdot \text{kg}^{-1}$) compared to CON

Reaction Time

Results from the 2-way repeated measure ANOVA revealed no significant group x time interaction for reaction time, $F(1,14) = 0.45, p = 0.51$ (Table 2.)

Table 2. Data (mean \pm SD) for comparison between NAP and CON conditions for morning and afternoon peak power in the 6 s cycle test and reaction time, including p -value and effect size comparison between conditions for both time points (PRE = morning, POST = afternoon).

					Group x Time interaction	
		PRE	POST	Change	p -value	ES (d) \pm 90% CI
Absolute Peak Power (W)	NAP	1582.5 \pm 170.9	1699.4 \pm 193.3 [#]	116.8 \pm 28.6 [#]	<0.01	0.72 \pm 0.27,
	CON	1624.8 \pm 200.2	1584.0 \pm 225.5	-40.8 \pm 24.6		<i>moderate</i>
Relative Peak Power (W.kg ⁻¹)	NAP	15.0 \pm 1.2	16.1 \pm 1.6 [#]	1.1 \pm 0.2 [#]	<0.01	0.80 \pm 0.29,
	CON	15.4 \pm 1.3	15.0 \pm 1.8	-0.4 \pm 0.2		<i>Large</i>
Reaction Time (ms)	NAP	353.6 \pm 16.9	346.5 \pm 19.7	-7.1 \pm 4.6	0.51	0.21 \pm 0.56,
	CON	351.8 \pm 19.1	349.1 \pm 20.9	-2.7 \pm 4.5		<i>unclear</i>

[#] Indicates a significant difference between pre and post measures ($p < 0.05$), [^] Indicates a significant difference between NAP and CON ($p < 0.05$) at the POST time point.

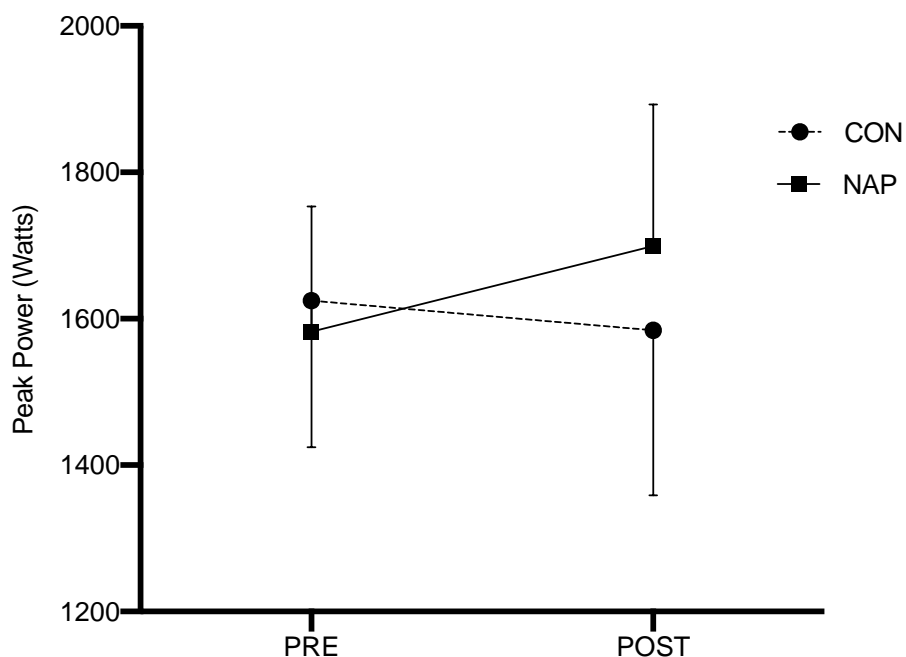


Figure 2. Mean 6s peak power (W) from PRE (morning) to POST (afternoon) timepoints for the NAP and CON trials. Error bars represent standard deviations. * significant group x time interaction.

Afternoon performance

Analysis of the fixed intensity cycle session revealed no significant ($p > 0.05$) differences for mean power output (191.6 ± 30.5 W vs. 194.5 ± 24.9 W, $p = 0.65$) or average heart rate (150 ± 8 vs. 152 ± 10 beats·min⁻¹, $p = 0.37$) between CON and NAP conditions. However, a significant difference ($p < 0.01$, $d = 1.75$) was observed in RPE scores between conditions, with the NAP condition reporting a lower RPE (6.6 ± 0.7 AU) than the CON condition (7.8 ± 0.6 AU).

Analysis of the 4-minute time trial showed no differences between NAP and CON for relative or mean power output or average heart rate (Table 3).

Table 3. Data (mean \pm SD) for comparison of mean power, relative power, average heart rate and rating of perceived exertion results from the 4-minute time trial between NAP and CON conditions, including p -value and effect size comparison between conditions

Measure	Condition	Mean \pm SD	p -Value	ES (d) \pm 90% CI
Mean power (W)	NAP	316.8 ± 46.8	0.39	0.09 ± 0.24 , <i>trivial</i>
	CON	312.6 ± 41.3		
Relative Power (W·kg ⁻¹)	NAP	3.0 ± 0.4	0.82	0.11 ± 0.26 , <i>trivial</i>
	CON	2.9 ± 0.3		
Average Heart Rate (beats·min ⁻¹)	NAP	163 ± 10	0.93	0.00 ± 0.30 , <i>unclear</i>
	CON	163 ± 9		

Subjective measures

Results from the 2-way repeated measure ANOVA revealed a significant group x time interaction for fatigue, $F(1,14) = 5.38$, $p = 0.03$ and general muscle soreness, $F(1,14) = 4.67$, $p = 0.04$, but not for alertness, $F(1,14) = 3.33$, $p = 0.08$. A main effect of time was observed for fatigue and general muscle soreness. Post-hoc testing showed that the NAP condition displayed significantly ($p = 0.01$) lower fatigue scores compared to the CON condition at the POST time point. Conversely, the CON condition displayed significantly ($p = 0.03$) lower general muscle soreness scores at the PRE time point compared to the NAP condition. Additionally, a *small* effect was observed for change in fatigue and *moderate* effects were observed for changes in general muscle soreness and alertness, both in favour of the NAP condition (Table 4.)

Table 4. Data (mean \pm SD) for comparison between NAP and CON conditions for morning and afternoon fatigue, general muscle soreness, and alertness, including p -value and effect size comparison between conditions for both time points (PRE = morning, POST = afternoon).

		Group x Time interaction				
		PRE	POST	Change	p -value	ES (d) \pm 90% CI
Fatigue (AU)	NAP	3.8 \pm 0.7	3.6 \pm 1.5 *	-0.2 \pm 1.4#	0.03	0.48 \pm 0.37, <i>small</i>
	CON	4.0 \pm 1.0	4.5 \pm 1.0	0.5 \pm 1.2		
General Muscle Soreness (AU)	NAP	4.3 \pm 1.0	4.2 \pm 0.8	-0.1 \pm 0.9	0.04	0.75 \pm 0.61, <i>moderate</i>
	CON	3.7 \pm 0.9 ^	4.4 \pm 1.4	0.7 \pm 1.6		
Alertness (AU)	NAP	3.7 \pm 0.8	3.4 \pm 1.5	-0.3 \pm 1.8	0.08	0.66 \pm 0.64, <i>moderate</i>
	CON	3.4 \pm 1.1	4.0 \pm 1.1	0.6 \pm 1.6		

Indicates a significant difference between PRE and POST measures ($p < 0.05$), ^ Indicates a significant difference between NAP and CON ($p < 0.05$) at the PRE time point. * Indicates a significant difference between NAP and CON ($p < 0.05$) at the POST time point

DISCUSSION

The aim of the current study was to examine the effects of a short daytime nap following morning training on afternoon performance in a cohort of professional rugby union athletes. Findings suggest utilizing a daytime nap of less than 1 hour (average of ~ 35 minutes) supported afternoon peak 6-second cycling improvements, lowered afternoon perception of exertion during exercise, and improved afternoon levels of fatigue and general muscle soreness. Therefore, we can conclude from these results that using a short daytime nap following morning training may support aspects of physical and perceptual recovery in the afternoon amongst professional rugby union athletes and may be a useful strategy to implement in these settings.

Whilst this study is the first to evaluate the effects of a daytime nap on afternoon performance in professional rugby union athletes, previous research has evaluated the effects of short daytime naps on physical performance in other cohorts. O'Donnell et al. (2018) showed that a 20-minute nap in the mid-afternoon resulted in improved countermovement jump peak velocity amongst elite netball athletes on match days. Additionally, Daaloul et al. (2019) reported that a 20-minute nap following sport-specific training that induced fatigue improved squat jump and countermovement jump performance amongst elite-level karate athletes. Our findings support the beneficial effects of a short nap on physical performance, with athletes displaying increased peak and absolute peak power following a short ~35-minute nap. Moreover, the NAP condition resulted in athletes displaying *moderate* to *large* improvements in peak and relative power

between the morning and afternoon. In contrast, the CON displayed a decrease in peak and relative power between the morning and afternoon.

It is likely that the increase in peak and relative power following the nap condition observed in the current investigation is multifactorial. Although speculative, one possible mechanism is that elevated cortisol levels that have been observed following a daytime nap (Vgontzas *et al.*, 2007) may have been associated with better neuromuscular performance (Passelergue, Robert and Lac, 1995; Crewther *et al.*, 2009). Indeed, the 6-second cycling test in the current investigation relies heavily upon high neuromuscular function for optimal performance (Douglas, Ross and Martin, 2021). Neuromuscular fatigue has been shown to affect force capabilities, including strength and power (Alba-Jiménez, Moreno-Doutres and Peña, 2022), altered movement strategies (Kennedy and Drake, 2017), and how team sport athletes produce high-intensity activities (Mooney *et al.*, 2013). Force capabilities and locomotive movement are important aspects of performance in training and competition amongst rugby union athletes (Crewther *et al.*, 2009). Therefore, the findings of a nap supporting neuromuscular performance may be important for afternoon training performance in athlete populations.

An additional benefit of daytime naps previously reported is that naps may reduce the perception of effort during exercise. Indeed, Blanchfield *et al.* (2018) reported that after a 20-minute nap, athletes cited a lower sense of effort via assessment of RPE at the end of a time to exhaustion exercise protocol in a cohort of trained endurance runners. Our results

align with previous findings, with athletes reporting lower RPEs for the fixed-intensity cycling session (6.6 Vs 7.8 AU in the NAP and CON groups, respectively). The differences observed in RPE in the current investigation may be due to differing levels of physical fatigue between the nap and no-nap conditions. Previous research has proposed that RPE scores during constant exercise are a direct function of workload (Myles, 1985), suggesting that fatigue is a possible stimulus for increases in RPE scores during exercise (Myles, 1985). Therefore, the finding from the current investigation may indicate that the nap provided improved physical recovery from the morning training session, which resulted in lower ratings of exertion in the afternoon.

Measures of fatigue, sleepiness and alertness have been reported to improve after a daytime nap (Tietzel and Lack, 2001). We observed that the nap condition displayed significantly lower levels of subjective fatigue and a *moderate* reduction in general muscle soreness in the afternoon compared to the no-nap condition, which may support the suggestion that a short daytime nap supports physical recovery. Previous research agrees with the findings from the current investigation; Bourkhris et al. (2020) reported that a 40-minute daytime nap resulted in decreased subjective fatigue and delayed onset muscle soreness compared to not taking a nap. The finding that a daytime nap reduces fatigue and muscle soreness observed in the current investigation is of importance amongst team sport athletes. Indeed, fatigue has been suggested to impact decision-making amongst athlete populations (Halsen, 2014). Effective and accurate decision-making is important for skill execution and has been suggested as fundamental for success in rugby performance (Sherwood, Smith and Masters, 2019). Furthermore, general muscle soreness has been suggested to

negatively impact neuromuscular performance (Byrne, Twist and Eston, 2004) and be linked to measures of decreased performance in rugby (McLean *et al.*, 2010). Therefore, it may be suggested that reducing muscle soreness may be important for sporting performance in rugby union athletes. Subsequently, these findings are of high relevance and importance amongst professional athlete populations who train more than once per day.

One possible explanation for the current findings of fatigue and general muscle soreness may be linked to levels of cytokines such as interleukin-6 (IL 6) following the nap. Increased levels of IL 6 have been observed following physical exercise (Steensberg *et al.*, 2000) and has been associated with muscle damage (Bruunsgaard *et al.*, 1997) and heightened sensations of fatigue (Robson-Ansley *et al.*, 2004). Additionally, levels of IL 6 have been shown to be suppressed following a daytime nap (Vgontzas *et al.*, 2007). Another plausible factor that needs to be considered is that the daytime nap relieved sleep pressure and adenosine build-up in the brain, which both increase throughout wake periods (Porkka-Heiskanen, 1999). Sleep pressure has been shown to increase in the afternoon (Monk, 2005; Bes *et al.*, 2009) and has been associated with reductions in alertness and increased fatigue (Askaripoor *et al.*, 2019). Furthermore, adenosine build-up inhibits neurotransmitters within the brain, causing an increase in sleepiness and negatively affecting alertness and fatigue (Van Dongen and Dinges, 2000).

No differences were observed between conditions for reaction time or subjective alertness. The lack of change in alertness and reaction time is contrary to previous results by Daaloul

et al. (2019), who demonstrated improvements in alertness and cognitive performance following a 30-minute daytime nap. The findings in the current investigation may partly be explained by a degree of sleep inertia present following the nap. Sleep inertia has been shown to impair subjective alertness and cognitive performance, including reaction time following awakening (Achermann *et al.*, 1995). Additionally, it has been shown that sleep inertia can impair alertness and cognitive performance for up to 2 hours after waking (Jewett *et al.*, 1999). Indeed, within the current investigation, we allowed 30-minutes between waking and reaction time testing; however, it is possible that sleep inertia was still present 30-minutes post-nap, impacting subjective alertness and reaction time performance.

Given the applied nature of the present study and the difficulty of conducting research on professional athletes, there are several limitations that we acknowledge. The nap duration and confirmation of being able to nap during the 1 hour was self-reported by athletes, which relied on athletes to assess whether they actually fell asleep, and we were unable to confirm napping via polysomnography or other objective measures. However, current study aimed to produce an ecologically valid piece of research. Implementing objective measures such as polysomnography was not practical and would have impacted the ecological validity of the research. Furthermore, an addition to strengthen the current study design would have been to collect information about athletes habitual napping behaviors. This data would enable comparisons between nap duration between habitual and non-habitual nap takers and evaluate if habitual nap takers performed better in the study. Moreover, we observed sleep duration was high compared to other studies involving professional rugby union

athletes. Therefore, it must be considered that sleep duration may have been artificially elevated due to athletes knowing their sleep was being monitored. We also acknowledge that sleep inertia following a nap is highly individual (Ritchie *et al.*, 2017) and that the 30-minute duration between napping and post-testing measures may not have been enough time for some participants to wake up and feel alert.

CONCLUSION

The current investigation investigated the impact of a daytime nap on afternoon performance and subjective measures in professional rugby union athletes. The results suggest that when athletes take a short nap of around 35 minutes, there was an increase in afternoon peak power production, reduced subjective fatigue, less general muscle soreness and lowered perceived exertion during afternoon training compared to not taking a nap between sessions. The findings from the current study suggest that napping may support recovery between training sessions on the same day and may provide positive effects on afternoon performance amongst professional rugby union athletes. Coaches and performance staff should consider allowing time between training sessions on the same day to provide athletes with an opportunity to take a daytime nap to help improve afternoon training performance.

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