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ARTICLE

Effect of mattress on actigraphy-based sleep quality and perceived recovery in top-level athletes: a randomized, double-blind, controlled trial

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ABSTRACT

This study aimed to evaluate the effect of a new mattress on sleep quality, perceived pain and recovery, and physical performance in top-level athletes. Twenty-five volleyball players were randomized to either an intervention group (INT, n = 13) or a control group (CON, n = 12). Sleep data were collected by actigraphy and Pittsburgh Sleep Quality Index (PSQI), perceived pain was evaluated by the Numeric Rating Scale (NRS), perceived recovery with the Total Quality Recovery scale (TQR), and physical performance with the Counter Movement Jump (CMJ) and Reaction Time (RT) tests. All evaluations were carried out during the competitive season at baseline condition (PRE) and four weeks later (POST). All actigraph parameters, PSQI, and NRS values improved for INT but not for CON while no differences were observed in CMJ and RT for both groups. TQR was higher for INT at POST compared to CON. A 4-weeks use of high-quality mattress could be beneficial for players' sleep, pain, and recovery.

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KEYWORDS
Sleep; recovery; athlete; injury; low-back pain; orthopedics

Introduction

Sleep plays an essential role for human health, and it is crucial for the recovery capacity in athletes as well (Samuels 2008). Recently, the International Olympic Committee underlined that athletes need to obtain sufficient sleep quantity and quality to promote global development and high-level performances but acute sleep deprivation is not unusual (Swinbourne et al. 2016; Taylor et al. 2016). It even seems that athletes, compared with non-athletes, tend to sleep less (less than the minimum recommendation of 7 h of sleep per night too) with lower sleep quality (Sargent et al. 2014). It has been reported, for instance, that NFL players had higher rates of obstructive sleep apnea together with greater levels of daytime sleepiness (Albuquerque et al. 2010) or that Olympic athletes took longer to fall asleep, had lower sleep efficiency, and higher sleep fragmentation than non-athlete individuals (Leeder et al. 2012). Evidence suggests that sleep problems are determined by several endogenous and exogenous factors, such as

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body temperature, subject's chronotype, training volume, anxiety, altitude, and many others (Suppiah et al. 2015; Silva et al. 2016; Vitale and Weydahl 2017), and they typically occur at two time frames for athletes. Disturbed sleep can be observed during regular training periods due to poor sleep hygiene (Bonnar et al. 2018) or in response to high-intensity or heavy training workloads (Vitale et al. 2017a). Most of the previous studies, aiming to test the impact of sleep debt on cognitive and physical performance, did not examine athlete's sleep in real-life conditions but in simulated cases of forced sleep loss (Fullagar et al. 2015). The few studies examining the effects of "real" partial sleep deprivation on physical performance showed that single sessions of maximal exercise are not significantly affected (Bonnar et al. 2018) while, conversely, sports-specific technical skills, reaction time, memory, and mood stability are more prone to impairment (Reilly and Edwards 2007; Vitale et al. 2017b).

It is therefore essential to identify and develop potential strategies for sleep optimization in athletes. Sleep hygiene typically aims to improve sleep related behaviors and encompasses all practices that are able to promote effective and restful sleep, including regularity of get-up and bed times, restriction of caffeine, correct nutrition, and control for environmental factors (e.g. room temperature and/or exposure to light) (Sateia 2014). Nonetheless, adherence to this sleep strategy can be challenging for athletes (Knufinke et al. 2018). In the light of these findings, it is crucial to understand if other alternative variables can be modulated or controlled in order to improve sleep quality in elite athletes. In this context, the sleeping environments, including mattress and pillow, could play an important role in quality of sleep (Lin and Deng 2008). A survey reported that sleep problems could occur due to uncomfortable mattress leading also to physical discomfort (Addison et al. 1986), and it was observed that different mattress or different mattress firmness could affect sleep and pain in a non-athlete population. (Kovacs et al. 2003). Nonetheless, the influence of the hardness of a mattress in sleep quality is subject of controversy (Bader and Engdal 2000). Moreover, to the best of our knowledge, no previous study examined the effect of a mattress on sleep, pain, and recovery in top-level athletes.

Therefore, the objective of the present randomized controlled trial was to evaluate the effect of a new high-quality and medium-firm mattress, utilized for four consecutive weeks, on actigraphy-based sleep parameters, subjective sleep quality, perceived pain and recovery, and on physical performance in elite volleyball athletes. We hypothesized to observe a significant impact of this mattress on both objective and subjective sleep quality and recovery but not on the players' physical performance.

Methods

Study design

A parallel two-groups, longitudinal (PRE–POST), experimental design was used for the present randomized, double-blind, controlled trial. The study was carried out over a 4-weeks period during the competitive season, in February 2017. All players were randomized in a 1:1 ratio to either an intervention group (INT, n = 13, 8 females and 5 males; age 25.8 ± 3.5 years) or a control group (CON, n = 12; 5 females and 7 males, age 26.3 ± 3.1 years). A computer-generated list of random numbers was used. INT group, after baseline evaluations, slept for three consecutive weeks on a different mattress while CON group continued to sleep on their habitual and standard mattress. The study flowchart is illustrated in Figure 1.

Participants

The study participants were professional volleyball players competing in the Italian First Division in two teams (*N* = 27; 14 males and 13 females, mean age (±SD) = 26.0 ± 3.4). All players started the competitive season in October 2016 and the intervention was carried

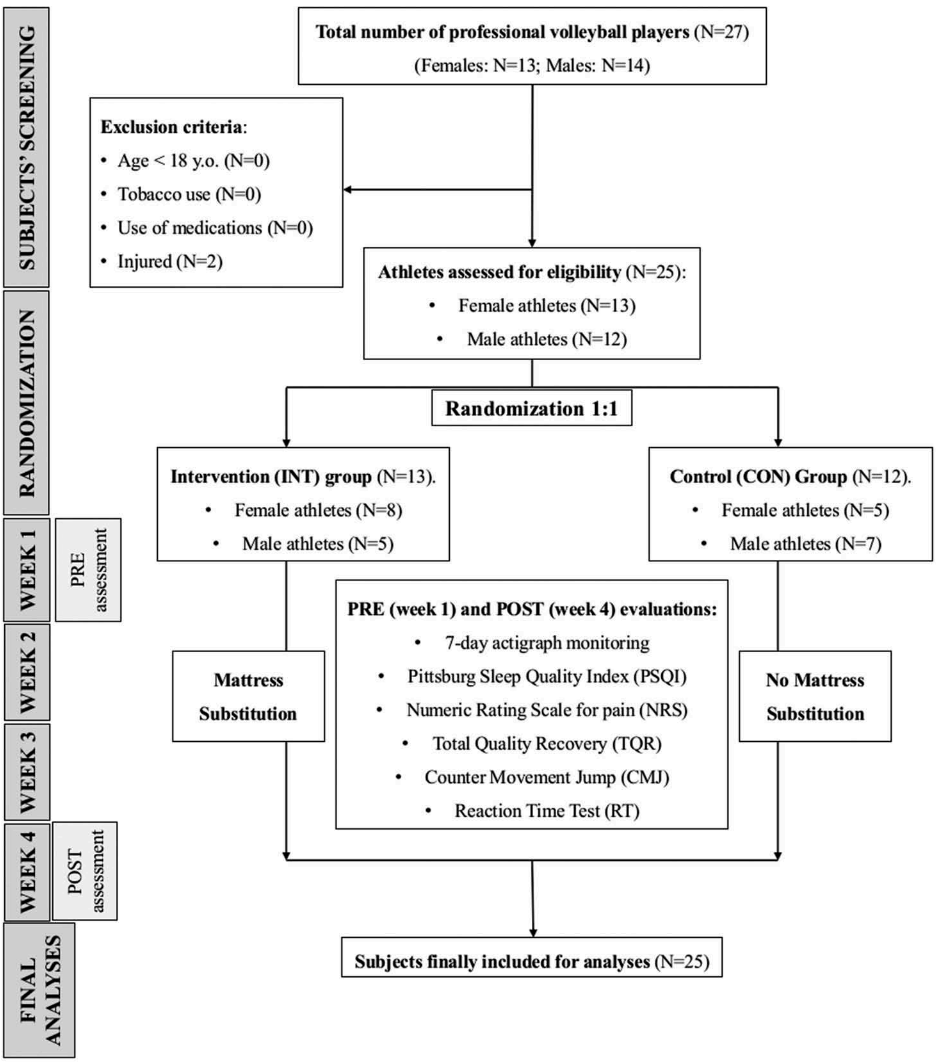

Figure 1. Flowchart for the study design and the participants' screening/selection according to the inclusion and exclusion criteria.

out in February 2017, during the "in-season period". Inclusion criteria were age >18 years and being a professional volleyball player with at least eight years of experience. Exclusion criteria were tobacco use, use of melatonin and/or medications, and medical conditions contraindicating physical exercise as diagnosed by a sports medicine physician. In total, among the 27 volleyball players screened, 25 were deemed eligible while 2 male athletes did not meet the inclusion criteria because injured (see Figure 1 for participants' screening). They were requested not to modify their usual diet, to abstain from extra training sessions during the study period. Before entering the study, all participants gave their written, informed consent and received an explanation of the purpose, methods, risks, and benefits of the experimental protocol. The study protocol was approved by the Institutional Ethics Review Committee of the Università degli Studi di Milano (Prot. N. 54/15) in compliance with current national and international laws and regulations governing the use of human subjects (Declaration of Helsinki II).

Mattress properties

Both INT and CON always slept in the same hotel for the entire competitive season. The new mattress used in this study for INT group, the MyForm ReActive mattress (Dorelan, B&T S.P.A., Forlì, Italy) was composed of three different layers: the upper and lower layers were identical and made of viscoelastic polyurethane foam of 7 cm (3.5 cm for each layer), while the intermediate layer was 15 cm thick and composed by double spiral springs in carbon (740 springs/m^2). Total mattress thickness was 22 cm and total density was 95 kg/m^3. On the contrary, all athletes of CON group slept on the same standard mattress composed by polyurethane foam, 15 cm thick, with a density of 40 kg/m^3. Both mattress sizes were 90 × 200 cm. To exclude possible effects of different covers, the same cover type and pillow were used throughout the entire study. Mattress features are described in Table 1

Procedures

The following assessments were carried out, for both INT and CON, in the first week of February 2017 (PRE) and in the fourth week of the same month end of experimental protocol (POST): (1) 7-days actigraph monitoring; (2) Pittsburg Sleep Quality Index (PSQI); (3) Numeric Rate Scale for Pain (NRS); (4) Total Quality of Recovery scale (TQR); (5)

Table 1. Mattresses characteristics. Technical characteristics of the standard mattress and MyForm ReActive mattress (Dorelan, B&T SPA, Forlì, Italy).

	Standard mattress—CON	MyForm ReActive—INT
Layers	One single layer: Foam: 15 cm	Three different layers: First Foam: 3.5 cm. Second Foam: Double spiral spring in carbon: 15 cm. Third Foam: 3.5 cm.
Thickness	15 cm	22 cm
Size	90 cm width × 200 cm large	90 cm width × 200 cm large.
Foam	Polyurethane	Viscoelastic polyurethane
Density	40 kg/m^3	95 kg/m^3
Time of use	5 years	New

INT: intervention group; CG: control group.

Counter Movement Jump test (CMJ); and (6) Reaction Test (RT). Evaluations with PSQI, NRS, TQR, CMJ, and RT were performed at the same time, on the same day of the week (Wednesday), at both PRE and POST, to avoid possible circadian differences.

Actigraph monitoring

All participants wore a wrist activity monitor, the Actiwatch 2 actigraph (Philips Respironics, OR, USA), to detect their sleep parameters. The actigraph monitoring lasted for 14 days in total, and splitted into two periods: sleep data were recorded for 7 days at PRE and for other 7 days at POST. We selected a high actigraphic sensitivity threshold to detect sleep parameters (80 counts/epoch) since it has been shown that it represents the best combination of sensitivity and specificity in a population of elite athletes (Sargent et al. 2016). Together with the actigraph, each subject received a sleep diary to record bed time, wake up time, hours napping, hours without wearing the actigraph, and the number of nocturnal awakenings. Data derived from the sleep diaries and wrist activity monitors were used to determine the quality of sleep participants obtained in one week. Five actigraph sleep parameters were measured:

(1) Sleep Efficiency (SE, %): the percentage of time in bed that was spent asleep.
(2) Sleep Latency (SL, minutes): the period of time between bedtime and sleep onset time.
(3) Fragmentation Index (FI, %). The sum of the percentages of mobility and immobility accesses in 1 min, divided by the number of immobility accesses.
(4) Immobility Time (IT, %). The total time, expressed in percentage, spent without recording any movement during time in bed.
(5) Wake After Sleep Onset (WASO, min): the amount of time spent awake after sleep has been initiated.

For automatic setting of sleep start the algorithm looks for a period of at least 10 min of consecutively recorded immobile data, with no more than 1 epoch of movement within that time, following the bed time.

Pittsburg Sleep Quality Index

General sleep quality was measured with the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989; Curcio et al. 2013). The PSQI is a 19-item self-report questionnaire assessing sleep quality over a 1-month period. Each answer scores range from 0 to 3 and the global score range from 0 to 21. A global score ≥ 5 was taken as an indicator of poor sleep quality (Samuels 2008).

Numeric Rating Scale for pain

The 11-item NRS for pain is a valid and reliable unidimensional measure of pain intensity in adults (Farrar et al. 2001). It is a segmented numeric version of the visual analog scale. The NRS is commonly showed as a horizontal bar and it is anchored by terms describing pain severity extremes (from 0 to 10), with 0 representing “no pain” and 10 representing "worst pain imaginable. Each subject was previously familiarized with the TQR scale, including anchoring procedures. The participants were asked in the morning, 1 h after waking up, to rate their perceived low-back pain.

Total quality Recovery scale

The TQR scale was developed to enable the measurement of the recovery process in sport (Kenttä and Hassmén 1998). It is a verbal-anchored scale proving a means to measure the athlete's psychophysiological recovery. The score ranges from 6 to 20, where 6 representing "no recovery at all" and 20 representing "maximum recovery". Each subject was previously familiarized with the TQR scale, including anchoring procedures. The participants were asked in the morning, 1 h after waking up, to rate their recovery as an overall psychophysiological rating for the previous night.

Counter Movement Jump

The procedures were carried out as described by Maulder and Cronin (2005) in which CMJ were performed on an Optojump Next (Microgate, Bolzano, Italy). In this setup, the Optojump photoelectric cells consisted of two parallel bars (one receiver and one transmitter unit) that were placed approximately 1 m apart and parallel to each other. The transmitter contains 32 light-emitting diodes positioned 3 mm above ground level at 31.25 mm intervals. The Optojump bars were connected to a personal computer. Jump height was measured using proprietary software (Optojump software; version 3.01.0001). The Optojump system measured the flight time of CMJ with an accuracy of 1 ms (1 kHz). Jump height was estimated using the following equation (Bosco et al. 1983):

$$h = \frac{gt_f^2}{8}$$

where h is the jump height, g is the gravitational acceleration (9.81 m$\cdot$ s^{-2}) and t_f is the flight time. After 15 min of standardized warm-up, the players performed three trials of CMJ. Take off was monitored with no preliminary steps of movement during the eccentric phase. The hands were kept on the hips during the CMJ, and both legs were used during the landing phase. Participants were allowed 20 s' recovery time between each trial. CMJ were executed starting from a standing position with feet aligned parallel. The best CMJ was recorded for analysis.

Reaction time

The Optojump system (Microgate, Bolzano, Italy) was used to evaluate RT too (Bosquet et al. 2009). The trial began with the athlete assuming a standing stance, with one foot (left or right) forward, facing the net on which a light source was located at a height of about 200 cm. A light stimulus was randomly generated between 1 and 3 s by the measuring system and the athlete had to react to the signal by running as quickly as possible toward the light. Electronic time recording started with the light source illuminating and ended with the removal of the heel of foot from the area located between the couple of the Optojump system. The best of three attempts was recorded for analysis.

Statistical analysis

The normality of the distribution of the participants' characteristics (age, height, weight, BMI, and training volume) at baseline was checked using the Shapiro–Wilk test. All data were normally distributed except for age (years) and training volume (h * week^{-1}). The unpaired Student's t test was applied to test the null hypothesis for no difference between INT and CON; the nonparametric Mann–Whitney rank test was used to compare the variables with no normal distribution.

Intra- and inter-group differences, between INT and CON at PRE and POST, for actigraphy-based sleep data, PSQI, TQR, NRS, CMJ, and RT were checked using two-way analysis of variance (2-Way ANOVA) with Bonferroni's multiple comparisons test. Standardized changes in the mean values were used to assess magnitude of effects (Effect Size, ES). Values <0.2, <0.6, <1.2, and >2.0 were interpreted as trivial, small, moderate, large, and very large, respectively (Batterham and Hopkins 2006). The level of significance was set at $p < 0.05$. Statistical analysis was performed using GraphPad Prism version 6.00 (GraphPad Software, San Diego, CA, USA).

Results

Unpaired t-test showed that INT and CON groups were equally matched, showing no significant differences in age, body mass, height, BMI, and weekly training volume. The players' characteristics are presented in Table 2.

Sleep parameters

In Figure 2 and Table 3 are shown the changes in SE, SL, FI, IT, and WASO for INT and CON before (PRE) and after (POST) the 4-weeks experimental protocol.

INT and CON had similar sleep behavior at baseline. Two-way analysis of variance with Bonferroni's multiple comparisons test showed for INT a PRE-to-POST improvement in SE (83.6 ± 4.2% versus 87.7 ± 3.6%, + 4.1%, $p < 0.05$, ES: 1.04), SL (15.1 ± 7.1 min versus 8.7 ± 7.2 min, – 6.4 min, $p < 0.01$, ES: 0.90), FI (29.4 ± 6.7% versus 23.1 ± 8.2%, –6.3%, $p < 0.05$, ES: 0.85), IT (86.3 ± 3.0% versus 88.6 ± 3.6%, –2.3%, $p < 0.01$; ES: 0.68), and WASO (50.2 ± 14.4 min versus 40.4 ± 16.8 min, –9.8 min, $p < 0.01$; ES: 0.63) whereas no significant differences for CON were detected (ES range: from 0.11 to 0.39). Significant interactions were observed only for SL ($p = 0.013$), IT ($p = 0.004$), and WASO ($p = 0.036$). In addition, several post-hoc inter-group differences were highlighted: all the actigraphy-based sleep

Table 2. Characteristics of INT and CON groups.

	INT *(N = 13)*	CON *(N = 12)*
Age (years)*	25.8 ± 3.5	26.3 ± 3.1 ^{ns}
Weight (kg)	82.5 ± 11.8	82.4 ± 16.9 ^{ns}
Height (m)	1.88 ± 0.09	1.87 ± 0.13 ^{ns}
BMI (kg * m^{-2})	23.1 ± 2.2	23.1 ± 1.8 ^{ns}
Training volume (h * week^{-1})*	22.5 ± 0.7	22.5 ± 0.7 ^{ns}

Comparison between INT and CON groups. The data are reported as mean ± SD.
* Age (years) and training (h * week^{-1}) variables were not normally distributed and were subjected to the nonparametric Mann–Whitney rank test. NS: no significant differences.
Legend: INT, Intervention group; CON, Control group; BMI, Body Mass Index.

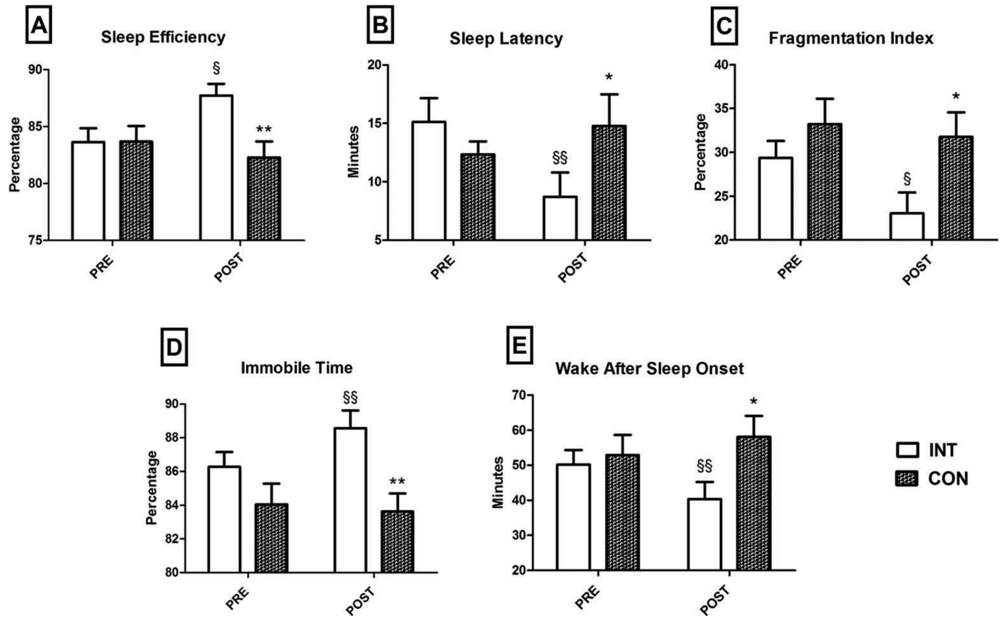

Figure 2. Changes in actigraphy-based sleep parameters (panel A: SE; panel B: SL; panel C: FI; panel D: IT; and panel E: WASO) before (PRE) and after (POST) the experimental protocol. Data are reported as mean ± SD.

Legend. INT: intervention group; CG: control group; *: inter-group difference with $p < 0.05$; **: inter-group difference with $p < 0.01$; §: intra-group difference with $p < 0.05$; §§: intra-group difference with $p < 0.05$.

parameters significantly differed at POST with INT showing better sleep patterns than CON (see Figure 2 and Table 3 for details).

Scales and questionnaires

In Figure 3 (panels A, B, and C) and Table 3 are displayed the changes in PSQI, TQR, and NRS for INT and CON. 2-way ANOVA showed significant interactions only for PSQI ($p = 0.0002$) and NRS ($p = 0.001$). Significant improvements over baseline evaluations were observed in INT for PSQI (4.8 ± 2.8% versus 2.9 ± 1.3, $p < 0.05$, ES: 1.07) and NRS (4.0 ± 2.8 versus 1.7 ± 1.8, $p < 0.05$, ES: 1.02), but not for TQR, whereas no significant differences for CON were detected. Post hoc inter-group differences were observed: INT had better significant results in PSQI ($p < 0.05$) and TQR ($p < 0.05$) than CON at POST; whereas, NRS values differed only at PRE between groups with CON showing lower results ($p < 0.05$) (see Table 3 and Figure 3 for details).

Physical tests

Referring to the physical tests, in Table 3 and Figure 3 (panels D and E) are reported the changes in CMJ and RT, and relative ES, before and after the 4-weeks of experimental protocol. Two-way analysis of variance with Bonferroni's multiple comparisons test did not reveal any significant difference between PRE and POST training for both INT and CON. Furthermore, no inter-group differences were detected.

Table 3. Data of actigraphy-based sleep parameters, scales, and questionnaires, and physical tests for INT and CON groups at PRE and POST.

	INT			CON				
	PRE	POST	Cohen's *d*	PRE	POST	Cohen's *d*	Interaction	Significance
SE (%)	83.6 ± 4.2	87.7 ± 3.6	1.04	83.7 ± 4.7	82.3 ± 4.9	0.29	ns	Time effect: INT: $p < 0.05$ INT vs CON: POST: $p < 0.01$
SL (min)	15.1 ± 7.1	8.7 ± 7.2	0.90	12.3 ± 3.7	14.8 ± 8.9	0.39	$p = 0.013$	Time effect: INT: $p < 0.01$ INT vs CON: POST: $p < 0.05$
FI (%)	29.4 ± 6.7	23.1 ± 8.2	0.85	33.2 ± 9.6	31.8 ± 9.2	0.15	ns	Time effect: INT: $p < 0.05$ INT vs CON: POST: $p < 0.05$
IT (%)	86.3 ± 3.0	88.6 ± 3.6	0.68	84.0 ± 4.1	83.6 ± 3.5	0.11	$p = 0.004$	Time effect: INT: $p < 0.01$ INT vs CON: POST: $p < 0.01$
WASO (min)	50.2 ± 14.4	40.4 ± 16.8	0.63	52.9 ± 19.1	58.1 ± 19.9	0.26	$p = 0.036$	Time effect: INT: $p < 0.01$ INT vs CON: POST: $p < 0.05$
PSQI	4.8 ± 2.8	2.9 ± 1.3	1.07	4.7 ± 1.3	4.9 ± 1.9	0.16	$p = 0.0002$	Time effect: INT: $p < 0.05$ INT vs CON: POST: $p < 0.05$
TQR (6-to-20 scale)	13.2 ± 2.6	15.2 ± 3.2	0.66	12.7 ± 2.9	13.2 ± 2.1	0.17	ns	Time effect: p = ns INT vs CON: POST: $p < 0.05$
NRS (1-to-10 scale)	4.0 ± 2.8	1.7 ± 1.8	1.02	1.8 ± 2.1	2.0 ± 2.1	0.10	$p = 0.001$	Time effect: INT: $p < 0.05$ INT vs CON: PRE: $p < 0.05$
CMJ (cm)	43.8 ± 5.8	43.2 ± 5.8	0.10	43.4 ± 10.2	42.8 ± 9.6	0.05	ns	Time effect: p = ns INT vs CON: p = ns
Reaction Time (s)	0.48 ± 0.05	0.49 ± 0.05	0.33	0.47 ± 0.06	0.46 ± 0.02	0.19	ns	Time effect: p = ns INT vs CON: p = ns

The table reports the results of the two-way ANOVA procedure with relative *p*-values and effect size (Cohen's *d*).
Legend. INT: intervention group; CON: control group; SE: Sleep Efficiency; SL: Sleep Latency; FI: Fragmentation Index; IT: Immobile Time; WASO: Wake After Sleep Onset; PSQI: Pittsburg Sleep Quality Index; TQR: Total Quality of Recovery scale; NRS: Numeric Rating Scale for pain; CMJ: Counter Movement Jump; RT: Reaction Time.

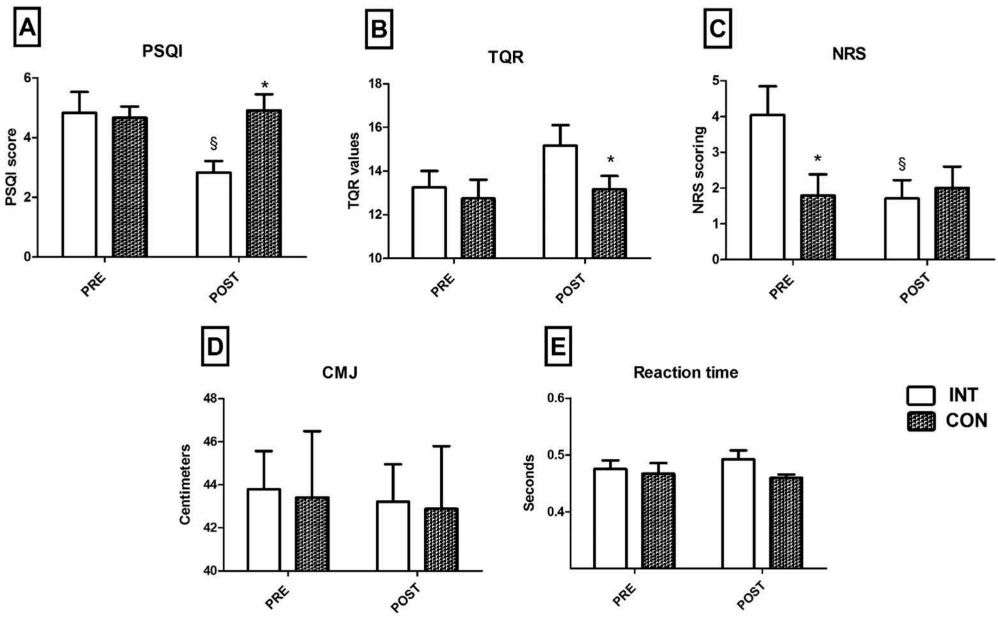

Figure 3. Changes PSQI (panel A), TQR (panel B), NRS (panel C), CMJ (panel D), and RT (panel E) before (PRE) and after (POST) the experimental protocol. Data are reported as mean ± SD.

Legend. INT: intervention group; CG: control group; PSQI: Pittsburg Sleep Quality Index; TQR: Total Quality of Recovery scale; NRS: Numeric Rating Scale for pain; CMJ: Counter Movement Jump; RT: Reaction Time; *: inter-group difference with $p < 0.05$; §: intra-group difference with $p < 0.05$.

Discussion

The main finding of this randomized controlled trial was that objective and subjective sleep quality, perceived recovery and pain, but not physical performance, were significantly affected by a 4-weeks use of a new mattress in top-level volleyball players. Specifically, INT improved all actigraph sleep parameters, PSQI, and NRS scores from PRE-to-POST condition while, conversely, CON did not modify any of the studied variables maintaining the same subjective and objective sleep quality. Furthermore, as expected, no differences were observed in CMJ and RT for both groups. Our initial hypotheses were all confirmed. To our knowledge, this was the first study that explored the use of a mattress as an alternative strategy to improve sleep in elite athletes.

The main function of the mattress should be to support the human body to allow the subject to properly recover and sleep. Even if it is commonly believed that changing sleep surfaces could improve sleep, the scientific literature in this research field is extremely scarce and the impact of mattress on sleep quality is still controversial (Radwan et al. 2015). Previous studies reported that unsuitable and low-quality mattress could determine insomnia complaints and lower sleep quality in non-athlete populations (Addison et al. 1986; Enck et al. 1999) while, Bader and Engdal (2000) did not observe a clear preference in healthy active middle-aged men for any one of the mattresses used in their study, neither firm nor soft. In general, the use of firm or medium-firm new mattress was associated with lower drug treatment and relevant improvements in pain and sleep quality (Kovacs et al. 2003; Tonetti et al. 2011a, 2011b); whereas, on the contrary, foam-made and soft mattress designs can actually create symptoms of pain in individuals with back problems (Jacobson et al. 2010). It is however important to highlight that specific categories of people are more sensitive to the firmness of mattresses than others: young subjects usually sleep well, regardless the sleep surfaces; on the other hand, sleep in the elderly can be affected by too hard or too soft mattress (Kovacs et al. 2003).

Thus, even if previous reports have failed to demonstrate clear differences in sleep due to sleep surface, it seems that both firmness and quality of the mattress could play a key role for sleep behavior. Therefore, possible reasons that can explain the positive effect of MyForm ReActive mattress on top-level players' sleep are the higher thickness (22 cm vs 15 cm), the higher density (40 kg/m^3 vs 95 kg/m^3), and the different composition (2 foam layers + 1 springs layer vs 1 single foam layer) compared to the old standard mattress. The two mattresses had then inherent significant technical differences (see Table 1 for details), mostly including density and hardness, which suggested the use of a higher firm mattress. The underlying mechanisms explaining our results are probably related to the duration of exposure to the mattress and to the effect of its firmness on pressure distribution and muscular function in bed.

One of the major strengths of this trial was that we used a randomized, double-blind, controlled trial while most of the previous studies testing the effects of the mattress were not blinded adequately. Nonetheless, although players were unaware of the type of mattress they were receiving after baseline evaluations, INT generally perceived the replacement of the mattress. A second strength was that we collected both objective and subjective sleep data to have a complete overview of the athlete's behavior and perception. Polysomnography represents the gold standard method to objectively study sleep/wake parameters but, due to the expensive equipment and because it is not easily portable, it is not commonly used with athletes; conversely, wrist activity monitors are valid and simple tools to study sleep with minimal effort on behalf of the athlete (Ancoli-Israel et al. 2003). Typically, actigraph monitoring reveals suboptimal sleep, with low sleep efficiency and long duration, in athletes (Taylor et al. 2016); however, it is still not clear to what extent athletes perceived their sleep as non-sufficient. Hence, assessing subjective sleep and quality is extremely useful to understand players' sleep need and recovery status (Krystal and Edinger 2008). We observed that INT and CON had similar objective and subjective values at baseline while only INT, after four weeks of use of the new mattress, increased SE and IT and decreased SL, FI, and WASO parameters highlighting a clear improvement, with large effect sizes, of objective sleep quality. Subjective data by PSQI and TQR revealed the same significant trend for the players that slept on MyForm Reactive bed. Finally, we also evaluated the athletes' perceived pain with NRS registering a significant reduction of pain only for INT but not for CON; however, baseline values for pain were not comparable with INT showing double NRS results compared to CON.

Another strength of the present trial is that we monitored athletes in real-life conditions, without forced partial or total sleep deprivation, and without any kind of alteration to their habitual training and sleep-wake schedules. It seems more pertinent and correct to investigate the effect of "real" and "natural" sleep restriction in elite athletes. In this context, we observed that our sample of top-level volleyball players registered, in general, objective and subjective sleep values similar to other sports disciplines, such as, basketball, soccer, rugby, running, and swimming (Lastella et al. 2015).

For what concerns the physical tests, we did not observe significant differences in jump and reaction performances, evaluated with the Optojump system, for both INT and CON. This was an expected result since, based on previous evidence (Fullagar et al. 2015), it has been widely demonstrated that single sessions of maximal exercise are unlikely affected by sleep restriction, much less it seems possible that a short-term physical performance could be directly influenced only by an improvement in sleep quality (Thun et al. 2015). On the contrary, significant variations in sleep quality and quantity in athletes could more easily and negatively influence cognitive performance, mood response, memory, decision-making ability, and, generally, the psycho-physiological responses to a physical performance (Bonato et al. 2017a, 2017b).

This study has some limitations and, above all, the lack of control of room temperature and light exposure, which are variables potentially able to affect sleep, could be considered a bias. No evaluation of athletes' chronotype has been performed and computation of power calculations should have been done to be sure that the sample was large enough to properly test the effect of the mattress. Firmness, that is independent of the composition of the mattress, was defined as medium for Myform ReActive mattress (recorded objective value: 3 KPa) but we were not able to obtain the specific value for the old standard mattress. Nonetheless, INT reported higher perceived firmness referring to the new mattress (8.2 ± 0.8) compared to the old one (5.0 ± 1.1). Another important variable that must be well defined in the future is the choice of the type of physical/cognitive tests to be associated with sleep parameters.

Conclusion

Studies in the scientific literature are insufficient to provide reliable indications about the effect of different kinds of mattress on sleep in top-level athletes. We observed that a 4-weeks use of high-quality and medium-firm mattress could be beneficial for players' sleep, pain, and recovery. Therefore, professional team players should be educated on the appropriate activities, daily living behaviors (such as what kind of mattress to use), and sleep hygiene recommendations to prevent sleep problems and possible worsening of their health status and physical performance. These results can be utilized by athletic trainers and medical staff to develop a greater knowledge of how sleep could be influenced by different sleep environments and, consequently, to implement alternative behavioral strategies in top-level athletes.

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Disclosure statement

Two of the authors of this paper, J.A.V. and A.LT, have disclosed potential conflict of interest which include receipt of payment as scientific consultants by Dorelan B&T S.P.A. (Forlì,Italy).

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