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The sleep of elite athletes at sea level and high altitude: a comparison of sea-level natives and high-altitude natives (ISA3600)

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Accepted 3 September 2013

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To cite: Roach GD, Schmidt WF, Aughey RJ, *et al*. *Br J Sports Med* 2013;**47**:i114–i120.

ABSTRACT

Background Altitude exposure causes acute sleep disruption in non-athletes, but little is known about its effects in elite athletes. The aim of this study was to examine the effects of altitude on two groups of elite athletes, that is, sea-level natives and high-altitude natives.

Methods Sea-level natives were members of the Australian under-17 soccer team (n=14). High-altitude natives were members of a Bolivian under-20 club team (n=12). Teams participated in an 18-day (19 nights) training camp in Bolivia, with 6 nights at near sea level in Santa Cruz (430 m) and 13 nights at high altitude in La Paz (3600 m). Sleep was assessed on every day/night using activity monitors.

Results The Australians' sleep was shorter, and of poorer quality, on the first night at altitude compared with sea level. Sleep quality returned to normal by the end of the first week at altitude, but sleep quantity had still not stabilised at its normal level after 2 weeks. The quantity and quality of sleep obtained by the Bolivians was similar, or greater, on all nights at altitude compared with sea level. The Australians tended to obtain more sleep than the Bolivians at sea level and altitude, but the quality of the Bolivians' sleep tended to be better than that of the Australians at altitude.

Conclusions Exposure to high altitude causes acute and chronic disruption to the sleep of elite athletes who are sea-level natives, but it does not affect the sleep of elite athletes who are high-altitude natives.

INTRODUCTION

Elite athletes who are native to sea level live and train for several days at terrestrial altitude in an attempt either to improve sports performance on return to sea level[1] or to minimise the impairment in sports performance in competition at altitude.[2] One of the factors that should be considered when weighing the costs and benefits of altitude training is its potential effects on athletes' sleep. Acute sleep disruption at altitude is a robust phenomenon, having been observed in non-athletes at high terrestrial altitude (ie, 4559–5050 m)[3–7] and recreational athletes at low-moderate simulated altitude (ie, 2000–2650 m).[8–11] Only one study, described in a companion paper in this issue,[12] has examined the effects of high terrestrial altitude (ie, 3600 m) on the sleep of elite athletes. That study showed that rapid eye movement (REM) sleep is reduced and 50% of athletes have severe disordered breathing, immediately on ascent to altitude from near sea level; and that REM sleep returns to normal, but disordered breathing does not improve, after 2 weeks of altitude exposure. Given that altitude training for sea-level natives is common and that various alternative methods are continually being developed and modified (eg, live high, train high; live high, train low; intermittent hypoxic training), more data regarding its potential effects, positive and negative, are required so that informed decisions about its use can be made.

While knowledge regarding the effects of altitude on the sleep of sea-level natives is growing, very little is known about the sleep of high-altitude natives at altitude, and even less is known about their sleep at sea level. Until now, no sleep studies with elite athletes who are native to high altitude have been conducted, and the studies that have been published with untrained adults have returned equivocal results. In each of these studies, high-altitude natives' sleep at high altitude is compared with normative data, rather than with a comparison group of sea-level natives at sea level. Two of these studies indicate that high-altitude natives and sea-level natives have similar sleep,[13 14] but three others indicate that high-altitude natives have more awakenings,[15] lower sleep efficiency,[15–17] less deep sleep[17] and less total sleep.[15 16]

The primary aim of this study was to examine and compare the sleep of two groups of elite athletes, that is, sea-level natives and high-altitude natives, while they lived and trained at high terrestrial altitude for several days. Taking an opportunistic approach, the secondary aim of this study was to examine potential adaptations in sleep after an eastward time zone change of 10 h in sea-level natives and after descending from high altitude to near sea level in high-altitude natives.

METHODS

Participants

Thirty-nine male soccer players volunteered to participate in the study. Twenty players were members of the Australian under-17 soccer team (the 'Joeys') and 19 players were members of a Bolivian under-20 club team (the 'Strongest'). For the main analyses reported here, players were included if their data set was at least 75% complete. Ultimately then, these analyses include data from 14 Australian players (age 15.6±0.5 years;

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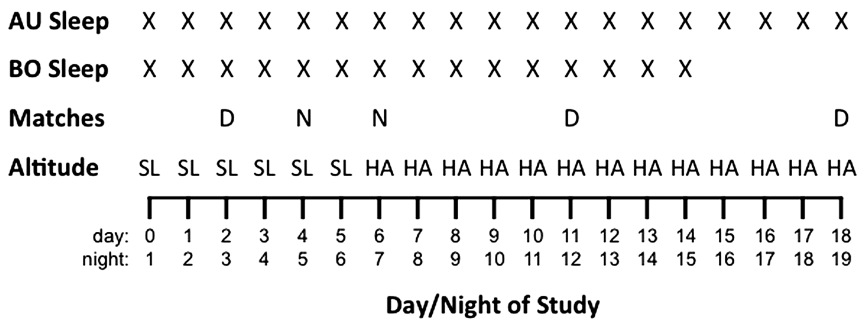

Figure 1 Sleep study protocol. The figure indicates when the teams were at near sea level (SL) and high altitude (HA); when daytime matches (D) and night-time matches (N) occurred between the teams; and when the Australians (AU) and Bolivians (BO) collected sleep data (X).

height 177±6 cm; mass 68.8±5.8 kg; mean±SD) and 12 Bolivian players (age 17.4±1.2 years; height 170±7 cm; mass 64.4±8.4 kg). The Australians were lifelong residents at sea level and the Bolivians were lifelong residents at high altitude. The study was approved by ethics committees at the Australian Institute of Sport and the Universidad Mayor de San Andrés. Written informed consent was obtained from participants (and their guardians if aged <18 years).

Protocol

In August 2012, the two teams participated in a training camp in Bolivia (figure 1) as part of the Australians' preparation for the 2012 Asian Soccer Confederation under-16 Championship. The camp was conducted over 18 days (and 19 nights)—the first six nights at near sea level in Santa Cruz (430 m) and the next 13 nights at high altitude in La Paz (3600 m). Immediately prior to the camp, the Australians travelled from Sydney, Australia, and the Bolivians travelled from La Paz. During the camp, the two teams played against each other in five friendly matches: two at near sea level and three at high altitude. A general description of the study methods and of the data related to blood gases, wellness, running performance, activity during matches and sleep architecture (for the Australians only) is reported in companion papers in this issue.[12 18–22]

Players from both teams were accommodated in two-person hotel rooms. Sleep/wake behaviour was monitored on all 18 days of the camp for the Australians and on the first 14 days for the Bolivians (which included match days and non-match days for both teams). The Bolivians were not monitored on the last 4 days because they had left the teams' hotel to return to their homes. When residing at the hotels, the players were required to attend a brief prebreakfast testing session by 09:30 on most days, but other than that they were free to chose their own bedtimes and get-up times.

The players' sleep/wake behaviour was monitored using self-report sleep diaries and activity monitors (Actical Z-series; Philips Respironics; Oregon, USA). The sleep diaries were used to record three pieces of information for night-time sleeps and daytime naps: start date/time, end date/time and subjective sleep quality. Each player wore an activity monitor, like a watch, on the same wrist throughout the study, except when showering or competing in matches. The activity monitors used in this study were configured to sum and store data in 1 min epochs based on activity counts from a piezoelectric accelerometer with a sensitivity of 0.05 g and a sampling rate of 32 Hz.

Measures

Data from the sleep diary and activity monitor were used in conjunction to determine when a player was awake/asleep (see figure 2 for an example). Essentially, all time was scored as wake unless: (1) the sleep diary indicated that the player was lying down attempting to sleep and (2) the activity counts from the monitor were sufficiently low to indicate that the player was immobile. When these two conditions were satisfied simultaneously, time was scored as sleep. This scoring process was conducted using Philips Respironics' Actiwatch algorithm with sensitivity set at 'high'.[23] The following variables were derived from the sleep diary and activity monitor data:

- Time in bed (h): the period between going to bed and getting up;
- Sleep onset (hh:mm): the time at which a player first fell asleep after going to bed;
- Sleep offset (hh:mm): the time at which a player last woke before getting up;
- Sleep period (h): the period between sleep onset and sleep offset;
- Total sleep time (h): the amount of sleep obtained during a sleep period;
- Cumulative sleep time (h): the sum of the total sleep times for a night sleep and any naps on the following day (for this variable, results are presented in tables and figures for completeness, but they are not mentioned in the text because naps were so rare that all values were similar to those for total sleep time);
- Sleep efficiency (%): total sleep time expressed as a percentage of the sleep period;
- Movement and Fragmentation Index: an index of sleep quality based on the level of activity, and the number of transitions between mobility and immobility, within a sleep period. Higher scores indicate sleep of poorer quality;
- Subjective sleep quality: Self-rating of sleep quality on a Likert scale, where 1 represents very poor and 5 represents very good.

Statistical analyses

To address the aims of the study, three types of comparisons were conducted for each of the dependent variables. First, the last five sleeps at sea level were each compared with the first sleep at sea level for each team separately. These comparisons enabled potential adaptations in sleep at near sea level to be examined—after a time zone change of 10 h to the east for the Australians, and after descending from high altitude for the Bolivians. Second, all sleeps at high altitude were compared with baseline sleep at near sea level, for each team separately, to examine potential disruption by, and adaption to, altitude exposure (the average of the last two sleeps at near sea level was used as the baseline so that any acute effects of sleeping in a new time zone (Australians) or at a lower altitude than normal (Bolivians) were minimised). Third, all sleeps for the Australians were compared with all sleeps for the Bolivians to examine potential differences between sea-level natives and high-altitude natives at near sea level and at high altitude. Finally, given that there is some evidence that competition exercise impairs the

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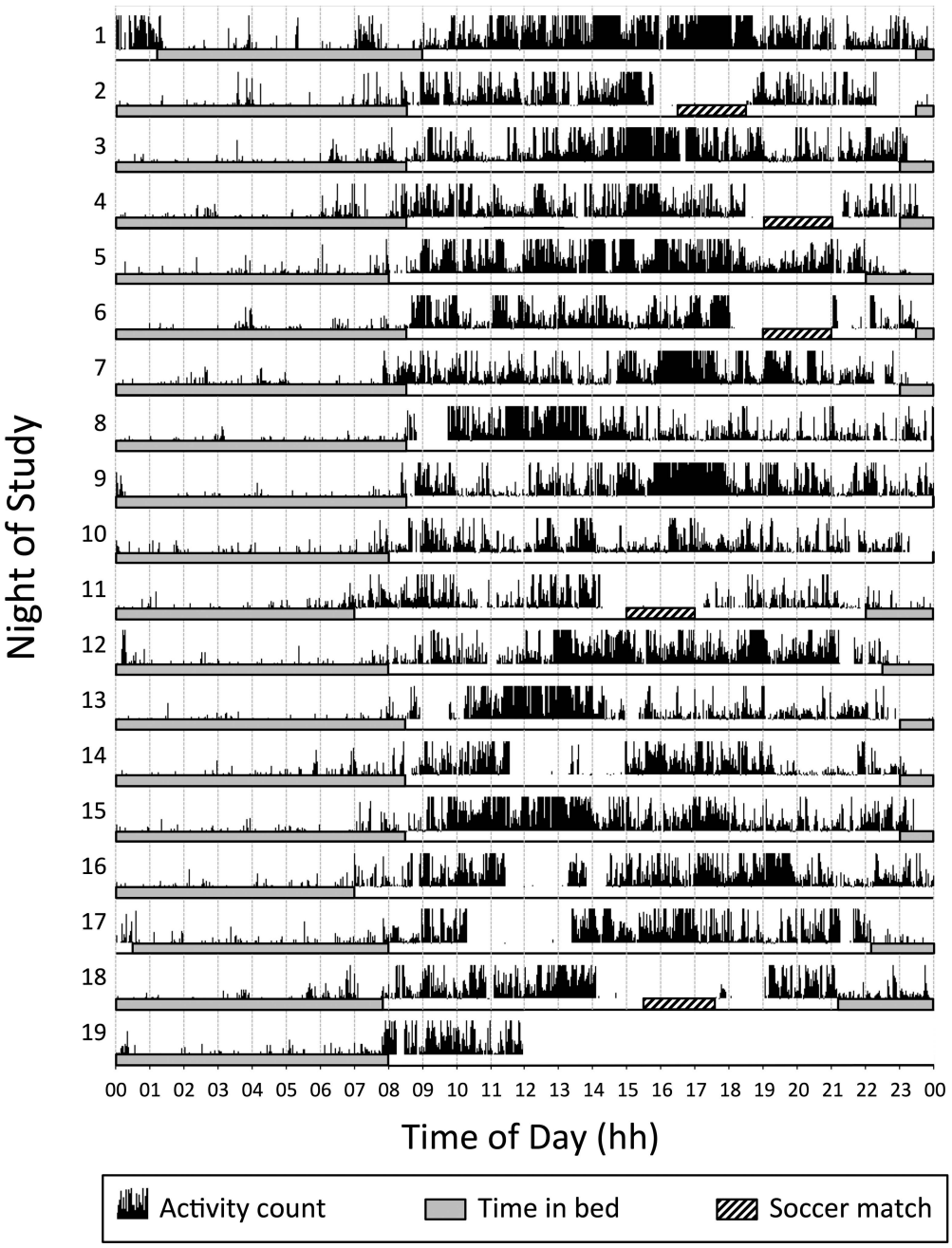

Figure 2 Example of one participant's sleep diary and activity monitor data for each day/night of the study. Black vertical bars represent activity counts recorded in 1-min epochs; grey horizontal bars represent time in bed; hatched horizontal bars represent soccer matches between the two teams.

subsequent sleep of elite athletes,[24] an additional set of analyses was conducted to compare sleep on match days with sleep on non-match days for each team separately. These additional analyses were conducted with a subset of the sample that included only athletes who played at least 45 min in a day match and at least 45 min in a night match (ie, 10 Australian players and 9 Bolivian players).

All dependent variables were log transformed to reduce bias due to non-uniformity of error. The magnitude of the observed effects for each comparison described above was assessed using standardised differences (effect size statistics) with a customised Excel-based spreadsheet.[25] For each variable, three separate probabilities were calculated using Student's t test to estimate the chances that the mean difference was positive, negligible or negative. For these analyses, the hypothesised difference, that is, the smallest worthwhile difference, was calculated as 0.5×the between-subject SD. A relatively conservative value was used for the smallest worthwhile difference (ie, 0.5 rather than the standard 0.2)[25] because the relationships between changes in sleep and changes in sports performance are not yet well quantified. The resultant probabilities were used to mechanically interpret the likelihood that an observed effect was a true effect using the following standards: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99%, very likely; >99%, almost certainly. Effects were accepted as substantial if the probability was >75%.

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Table 1 Sleep characteristics for sea-level natives and high-altitude natives

	Sea-level natives (Australians, n=14)			High-altitude natives (Bolivians, n=12)		
	Sleep type (mean (±SD))			Sleep type (mean (±SD))		
Variable	Sea level (average)	High altitude (acute)	High altitude (average)	Sea level (average)	High altitude (acute)	High altitude (average)
Time in bed (h)	9.2 (±0.8)	8.8 (±1.0)	9.1 (±0.7)	7.8 (±0.6)	8.0 (±0.8)	8.4 (±1.1)
Sleep onset (hh:mm)	23:40 (±0:47)	23:57 (±0:38)	00:02 (±0:46)	00:24 (±0:38)	00:17 (±0:31)	00:21 (±0:42)
Sleep offset (hh:mm)	08:25 (±0:37)	08:13 (±0:45)	08:28 (±0:34)	07:40 (±0:23)	07:50 (±0:40)	08:21 (±0:68)
Total sleep time (h)	7.0 (±0.5)	6.1 (±0.7)	6.5 (±0.7)	5.7 (±0.7)	5.9 (±0.9)	6.4 (±1.0)
Cumulative sleep time (h)	7.0 (±0.5)	6.1 (±0.7)	6.5 (±0.7)	5.7 (±0.7)	5.9 (±0.9)	6.4 (±1.0)
Sleep efficiency (%)	80 (±3)	75 (±5)	77 (±5)	78 (±6)	78 (±8)	80 (±6)
Move and Frag Index	25 (±6)	30 (±8)	29 (±7)	24 (±8)	26 (±10)	24 (±8)
Subjective sleep quality	3.8 (±0.7)	2.8 (±0.6)	3.8 (±0.6)	3.9 (±0.6)	4.2 (±0.4)	4.3 (±0.4)

Measures of sleep quantity and sleep quality for the Australians and Bolivians for (1) an average sleep at near sea level (based on the last two nights at near sea level), (2) the first sleep at high altitude and (3) an average sleep at high altitude (based on the last four nights that the Bolivians collected data).

RESULTS

Descriptive summaries (Australians and Bolivians)

The summaries of both teams' sleep are provided here, mainly as a benchmark for future comparisons (table 1). Data are based on individuals' mean values for nights 5 and 6, which correspond to both teams' last two sleeps at near sea level; night 7, which corresponds to both teams' first sleep at high altitude; and nights 12–15, which correspond to the Bolivians' last four nights of data collection at high altitude.

Sleep on match days and non-match days (Australians and Bolivians)

For the Australians, there were no substantial differences in any of the measures for sleep on days that included either a day match or a night match compared with sleep on non-match days (table 2). For the Bolivians, there were no substantial differences for the majority of the match day versus non-match day comparisons, but they spent more time in bed and obtained more sleep on days with a day match compared to non-match days, and they fell asleep earlier on days with a night match compared to non-match days (table 2).

Sleep at near sea level after eastward travel (Australians)

Quantity measures

Compared with the first night at near sea level, the Australians spent more time in bed on 4/5 nights (figure 3A), fell asleep earlier on 5/5 nights (figure 3B), woke up earlier on 1/5 nights (figure 3C) and obtained more sleep on 4/5 nights (figure 3D).

Table 2 Comparison of sleep characteristics on match days and non-match days

	Day type (mean (±SD))			Difference (effect size (±90% CI))		
Variable	No match	Day match	Night match	Day match vs no match	Night match vs no match	Night match vs day match
Sea-level natives (Australians, n=10)						
Time in bed (h)	9.0 (±0.4)	9.3 (±1.2)	9.0 (±1.0)	0.2 (±0.6)	0.0 (±0.4)	−0.2 (±0.5)
Sleep onset (hh:mm)	23:50 (±0:29)	00:10 (±0:75)	23:44 (±0:28)	0.3 (±0.7)	−0.1 (±0.3)	−0.5 (±0.6)
Sleep offset (hh:mm)	08:14 (±0:30)	08:10 (±0:53)	08:11 (±0:51)	−0.1 (±0.3)	−0.1 (±0.4)	0.0 (±0.3)
Total sleep time (h)	6.5 (±0.3)	6.2 (±1.0)	6.7 (±1.0)	−0.4 (±0.6)	0.2 (±0.5)	0.5 (±0.5)
Cumulative sleep time (h)	6.6 (±0.4)	6.2 (±1.0)	6.7 (±1.0)	−0.5 (±0.6)	0.1 (±0.4)	0.5 (±0.5)
Sleep efficiency (%)	77 (±3)	78 (±4)	79 (±3)	0.3 (±0.6)	0.6 (±0.7)	0.3 (±0.9)
Move and Frag Index	29 (±5)	28 (±6)	25 (±7)	−0.2 (±0.4)	−0.7 (±0.7)	−0.5 (±0.7)
Subjective sleep quality	3.7 (±0.4)	3.7 (±0.6)	3.4 (±0.5)	−0.1 (±0.6)	−0.7 (±0.7)	−0.5 (±0.8)
High-altitude natives (Bolivians, n=9)						
Time in bed (h)	7.9 (±0.3)	8.5 (±0.7)	8.3 (±0.6)	0.9 (±0.5) **L**	0.6 (±0.5)	−0.2 (±0.6)
Sleep onset (hh:mm)	00:28 (±0:17)	00:13 (±0:32)	23:56 (±0:25)	−0.5 (±0.5)	−1.1 (±0.5) **V**	−0.5 (±0.7)
Sleep offset (hh:mm)	07:49 (±0:18)	08:20 (±0:46)	07:51 (±0:42)	0.7 (±0.5)	0.0 (±0.5)	−0.5 (±0.5)
Total sleep time (h)	5.7 (±0.5)	6.4 (±0.7)	6.0 (±0.9)	0.8 (±0.4) **L**	0.4 (±0.4)	−0.4 (±0.4)
Cumulative sleep time (h)	5.7 (±0.5)	6.5 (±0.9)	6.0 (±0.9)	0.9 (±0.5) **L**	0.4 (±0.4)	−0.5 (±0.4)
Sleep efficiency (%)	77 (±4)	79 (±5)	76 (±6)	0.3 (±0.3)	−0.2 (±0.4)	−0.4 (±0.3)
Move and Frag Index	26 (±5)	24 (±8)	26 (±7)	−0.3 (±0.4)	0.0 (±0.5)	0.2 (±0.6)
Subjective sleep quality	3.8 (±0.3)	4.3 (±0.6)	4.0 (±0.0)	0.4 (±0.4)	0.2 (±0.4)	−0.3 (±0.7)

Measures of sleep quantity and sleep quality for the Australians and Bolivians for days on which the teams competed in no match, a day match and a night match. Comparisons between the measures for each type of day are presented as standardised differences (ie, effect size with 90% CI). The likelihood that an observed difference was a true difference is indicated by '**L**' if likely (ie, 75–95%) and '**V**' if very likely (ie, 95–99%).

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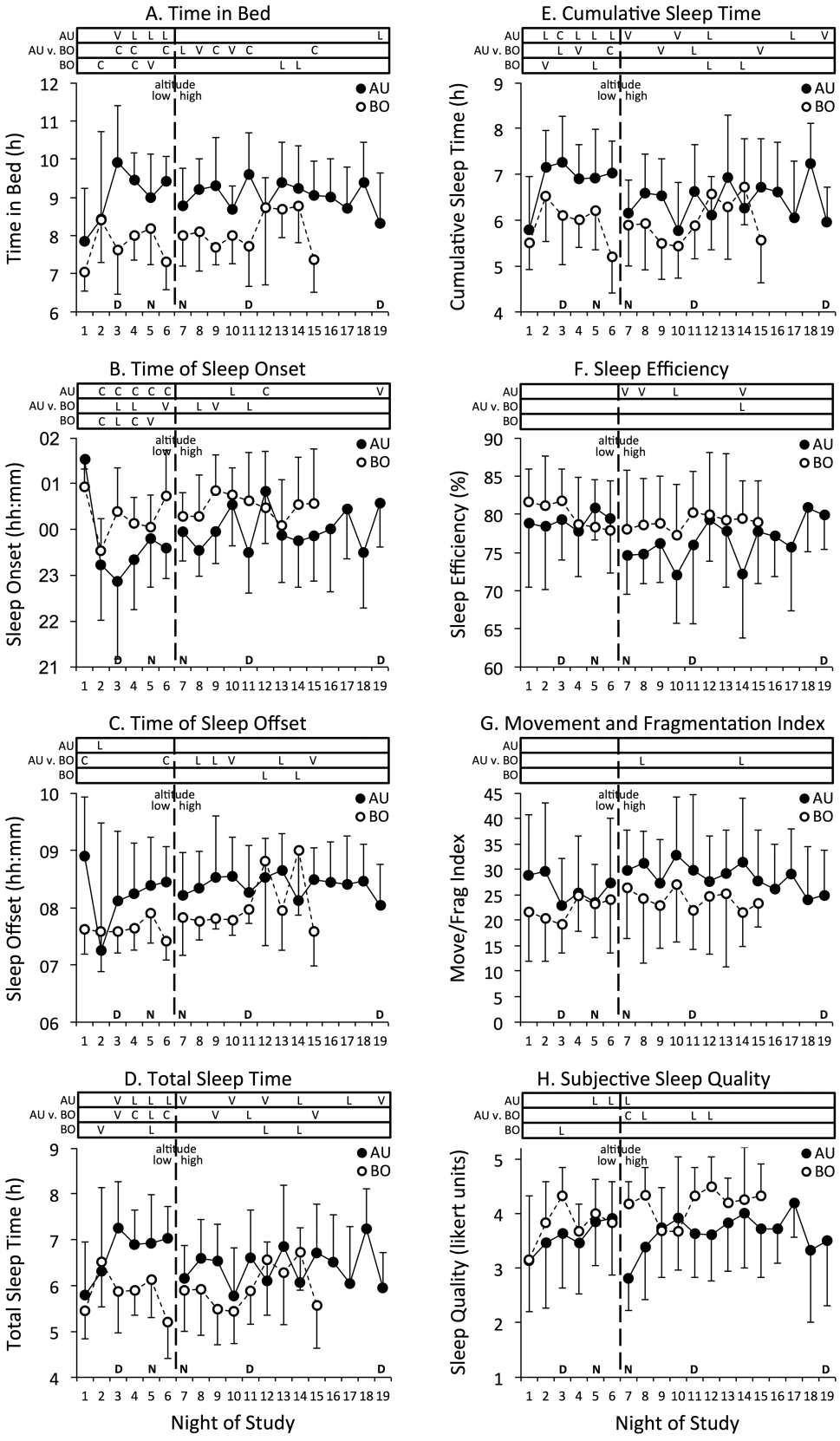

Figure 3 Variables related to the quantity and quality of sleep obtained by the Australians (n=14, closed circles) and Bolivians (n=12, open circles). Each of the panels A–H contains data related to a single variable, presented as mean±SD. At the top of each panel, the likelihood that an observed effect was a true effect is indicated by 'L' if likely (ie, 75–95%), 'V' if very likely (ie, 95–99%) and 'C' if almost certainly (ie, >99%). Effects are related to comparisons between (1) the last five sleeps at sea level and the first sleep at sea level (for the Australians (AU) and Bolivians (BO)); (2) all sleeps at high altitude and baseline sleep at near sea level (for the Australians (AU) and Bolivians (BO)) and (3) all sleeps for the Australians and all sleeps for the Bolivians (AU vs BO). Above the x-axis of each panel, nights that were immediately preceded by a soccer match are labelled with '**D**' for daytime matches and '**N**' for night-time matches.

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Quality measures

Compared with the first night at near sea level, the Australians had similar sleep efficiency on 5/5 nights (figure 3F), similar movement and fragmentation index on 5/5 nights (figure 3G) and higher subjective sleep quality on 2/5 nights (figure 3H).

Sleep at near sea level after descent from high altitude (Bolivians)

Quantity measures

Compared with the first night at near sea level, the Bolivians spent more time in bed on 3/5 nights (figure 3A), fell asleep earlier on 4/5 nights (figure 3B), woke up at a similar time on 5/5 nights (figure 3C) and obtained more sleep on 2/5 nights (figure 3D).

Quality measures

Compared with the first night at near sea level, the Bolivians had similar sleep efficiency on 5/5 nights (figure 3F), similar movement and fragmentation index on 5/5 nights (figure 3G) and higher subjective sleep quality on 1/5 nights (figure 3H).

Sleep at high altitude (Australians)

Quantity measures

Compared with the last two nights at near sea level, on the first night at high altitude, the Australians spent a similar amount of time in bed (figure 3A), fell asleep at a similar time (figure 3B), woke up at a similar time (figure 3C), but obtained less sleep (figure 3D). During the rest of the time at high altitude, the Australians spent less time in bed on 1/12 nights (figure 3A), fell asleep later on 3/12 nights (figure 3B), woke up at a similar time on 12/12 nights (figure 3C) and obtained less sleep on 5/12 nights (figure 3D), compared with the last two nights at near sea level.

Quality measures

Compared with the last two nights at near sea level, on the first night at high altitude, the Australians had lower sleep efficiency (figure 3F), similar movement and fragmentation index (figure 3G) and lower subjective sleep quality (figure 3H). During the rest of the time at high altitude, the Australians had lower sleep efficiency on 3/12 nights (figure 3F), similar movement and fragmentation index on 12/12 nights (figure 3G) and similar subjective sleep quality on 12/12 nights (figure 3H), compared with the last two nights at near sea level.

Sleep at high altitude (Bolivians)

Quantity measures

Compared with the last two nights at near sea level, on the first night at high altitude, the Bolivians spent a similar amount of time in bed (figure 3A), fell asleep at a similar time (figure 3B), woke up at a similar time (figure 3C) and obtained a similar amount of sleep (figure 3D). During the rest of the time at high altitude, the Bolivians spent more time in bed on 2/8 nights (figure 3A), fell asleep at a similar time on 8/8 nights (figure 3B), woke up later on 2/8 nights (figure 3C) and obtained more sleep on 2/8 nights (figure 3D), compared with the last two nights at near sea level.

Quality measures

Compared with the last two nights at near sea level, on the first night at high altitude, the Bolivians had similar sleep efficiency (figure 3F), similar movement and fragmentation index (figure 3G) and similar subjective sleep quality (figure 3H). During the rest of the time at high altitude, the Bolivians had similar sleep efficiency (figure 3F), movement and fragmentation index (figure 3G) and self-rated sleep quality (figure 3H) on 8/8 nights, compared with the last two nights at near sea level.

Sea-level natives (Australians) compared with high-altitude natives (Bolivians)

Time in bed

The Australians spent more time in bed than the Bolivians on 3/6 nights at near sea level and 6/9 nights at high altitude (figure 3A).

Sleep onset

The Australians fell asleep earlier than the Bolivians on 3/6 nights at near sea level and 3/9 nights at high altitude (figure 3B).

Sleep offset

The Australians woke up later than the Bolivians on 2/6 nights at near sea level and 5/9 nights at high altitude (figure 3C).

Total sleep time

The Australians obtained more sleep than the Bolivians on 4/6 nights at near sea level and 3/9 nights at high altitude (figure 3D).

Sleep efficiency

The Australians and Bolivians had similar sleep efficiency on 6/6 nights at near sea level, but the Australians had lower sleep efficiency than the Bolivians on 1/9 nights at high altitude (figure 3F).

Movement and fragmentation index

The Australians and Bolivians had similar movement and fragmentation index on 6/6 nights at near sea level, but the Australians had higher movement and fragmentation index than the Bolivians on 2/9 nights at high altitude (figure 3G).

Subjective sleep quality

The Australians and Bolivians had similar self-rated sleep quality on 6/6 nights at near sea level, but the Australians had lower self-rated sleep quality than the Bolivians on 4/9 nights at high altitude (figure 3H).

DISCUSSION

In this study, athletes' sleep was assessed using self-report diaries and wrist-worn activity monitors, that is, actigraphy, rather than the gold standard method, that is, polysomnography. Actigraphy has been validated for use in field-based settings,[23 26] and it has been used to assess the sleep of elite athletes from a variety of sports.[27 28] The main limitation of actigraphy is that it cannot discriminate between different stages of sleep (ie, light, deep and REM), which provide the best information about the quality of a sleep period. However, an important feature of actigraphy is that sleep data can be collected from several participants concurrently on multiple consecutive nights because (1) it is substantially less invasive than polysomnography and (2) the equipment is relatively inexpensive and does not need to be attended by a researcher.

There is some evidence that athletes' sleep is impaired by high training loads,[29] competition exercise[24] and the anticipation of competition.[30] In this study, however, match competition did not affect the Australians' sleep, and it improved some aspects of the Bolivians' sleep. It is unlikely that match competition substantially interfered with the comparisons discussed below, given that its effects on sleep were modest and sleep data were collected by both teams on match days and non-match days at both altitudes.

This is the first study to directly compare the sleep of sea-level natives (Australians) and high-altitude natives (Bolivians). It is

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possible that differences in the physiology of the two groups[31] were responsible for the Bolivians obtaining less sleep than the Australians at both altitudes, but there are equally valid alternative explanations. First, the Australians were 2 years younger than the Bolivians, which at this age could mean that they required more sleep.[32] Second, as the Bolivians lived in a culture with historical ties to the siesta, they may have been more likely to stay up later, obtain less sleep at night and supplement night-time sleep with daytime naps.[33] This second explanation is not supported by the napping data, but the fact that the Bolivians almost never napped may have occurred because the camp's schedule meant that opportunities to do so were rare.

The Australians had a rapid time zone shift of 10 h eastward immediately prior to the camp, so the fact that the quantity and self-perceived quality of their sleep was higher at the end of the first week of camp than it was at the start is to be expected. Athletes flying across several time zones to attend training camps or competitions should be aware of the disruption that may occur to their sleep/wake patterns. If athletes adhere to a schedule of sunlight exposure/avoidance based on the principles of circadian physiology,[34] as the Australians did in this study, then the rate of adaptation to the new time zone can be increased.[35] The Bolivians did not have to change time zones prior to the camp, but they did have to descend from high altitude. Their sleep improved to some extent over the week at sea level, but it is unclear whether poor sleep on the first night was caused by the change in altitude or the stressors associated with travelling and being inducted into the training camp.

A parallel study conducted with a subset of the Australians from this sample indicated that acute sleep disruption is resolved in sea-level natives after 2 weeks at high altitude.[12] However, the current study indicates that high altitude causes an acute reduction in the amount of sleep obtained by sea-level natives, and this effect continues intermittently for at least 2 weeks. In contrast, data from the Bolivians indicate that high-altitude natives sleep equally well at high altitude as they do at near sea level.

What are the new findings

- Exposure to high altitude causes acute and chronic disruption to the sleep of elite athletes who are sea-level natives.
- Exposure to high altitude does not disrupt the sleep of elite athletes who are high-altitude natives.
- Exposure to low altitude may cause acute disruption to the sleep of elite athletes who are high-altitude natives.

How might it impact on clinical practice in the near future

If good sleep is an important component of an athlete's preparation, then sea-level natives ascending to high altitude, and high-altitude natives descending to sea level, should have at least two nights of sleep at their competition altitude prior to competing.

Acknowledgements The authors sincerely thank the partner organisations (see ref. 21) and the Australian Research Council for their financial support; and the coaches, managers, support staff and players from both teams for their cooperation and assistance.

Contributors GDR and CS drafted the article and contributed to the conception and design, acquisition of data, analysis and interpretation of data and final approval of the article. WFS contributed to the conception and design, acquisition of data, critical revision of the article for important intellectual content and final approval of the article. RJA was involved in the analysis and interpretation of data, critically revised the article for important intellectual content and approved the final version of the article. PCB, RS, JCJC, LAG-L, BMS, KH, MK and NW were involved in the acquisition of data, critical revision of the article for important intellectual content and final approval of the article. MB was involved in the acquisition of data, analysis and interpretation of data, critical revision of the article for important intellectual content and final approval of the article. CJG contributed to the conception and design, critical revision of the article for important intellectual content and final approval of the article.

Funding Australian Research Council, Australian Institute of Sport, Victoria University, ASPIRE Zone Foundation.

Competing interests None.

Ethics approval Australian Institute of Sport Human Research Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med 2013 47: i114-i120
doi: 10.1136/bjsports-2013-092843

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