Effects of circadian rhythms on night-time swimming during the Olympics: The results of a pilot study in preparation for Rio 2016

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Abstract

Circadian rhythms (CRs), among other factors, have been shown to be crucial in sports performance. Unlike the usual timings for international events, the swimming competitions in the 2016 Olympics were held between 22.00 and 00.30. This means that the CRs of the swimmers will be shifted by five-hours. The impact of CRs on sporting performance is already known (Cappert T, 1999). Therefore, the aim of this study was to analyse sleep quality (SQ), heart rate variability (HRV), heart rate recovery (HRR) and the total mood disturbance (TMD) index during a week of night-time training and the influence they have on the state of overreaching. Three male swimmers, who competed in the sprint races during the 2016 Olympics in Rio, were monitored during a week of night-time training sessions to correspond with the timings of their evening races during the Olympics' semi-finals and finals. Assessments of SQ, in which the ratio of total time in bed was calculated using actigraphy (Sensewear, Bodymedia USA), HRR, HRV (Minicardio, Hosand – Italy) and TMD were conducted five times during the whole simulation exercise with intervals of two days and once on the habituation day. All athletes answered a "morningness/eveningness" questionnaire in relation to the chronotype profile (REF). The CRs were made to shift by five hours, such that the athletes woke up at 11.00 and went to bed at 02.00, while their nutritional intake was integrated with Tryptophan (an essential amino acid that is converted to serotonin, which in turn is converted to melatonin) in order to improve SQ. For each variable, a Univariate ANOVA with Time factor was used to compare the significant effects in-between sessions. When a significant F-value was found, least significant difference (LSD) was chosen as the post-hoc procedure. Meanwhile, a t-test was used to establish TMD on two occasions (at the beginning and at the end). The level of significance was fixed at $p<0.05$ using SPSS 15.0 Software. The Univariate ANOVA showed that, for HRV, which was classified in terms of Very Low Frequency (VLF), Low Frequency (LF) or High Frequency (HF), SQ showed significant effects between each time period (T0-T1-T2-T3-T4): F=9.481 and

p=0.002, F=6.603 and p=0.007, F=9.209 and p=0.002, F=19.189 and p<0.0001, respectively. Conversely, the Univariate ANOVA showed no significant effect on HRR, (F=0.817 and p=0.542). Finally, TMD was very low at the start (5.50±3.51) respect 81.00±18.90 during the last session (p=0.031).The data suggest that training late at night impaired the physiological and psychological states of the athletes. Increased sleep disturbance, fatigue and changes in autonomic functioning hinted at the onset of an overreached state.In the current study, the main findings indicated that there are effects on HRV, SQ and TMD. In conclusion, the time of day was shown to have a significant effect on the psychological and physiological variables observed in this study, thus indicating there are potential effects. More than two days under "late night" conditions can inhibit the performance of athletes, with a major impact on their "morningness" profile. In order to reduce such an impact, greater emphasis must be placed on identifying the nutritional and sleep needs of elite swimmers, in order to put together adequate recovery strategies that will help them train effectively to maximize performance outcomes.

Introduction

The 2016 Olympic Games consisted of 28 sports with a total of 298 disciplines and same number of gold medals. During the 15 days of competitions, athletes were engaged in achieving their maximum performance, according to the program that will start at 8.30 am and will end at 00:50 am.

Swimming, after Track and Field, with 47 medals, has 34 medals to be allocated and is scheduled at night with semifinals and finals between 10.00 pm. and 00.30 am. It is scheduled simultaneously with the Beach Volleyball competition (CIO, 2016). Various psychological and physiological parameters showed alterations if compared to daytime and nighttime hours. In particular, these alterations follow a time course during a whole day with peaks at some hours of the same. These sleep-wake or circadian variations are known as circadian rhythms (CRs. However, the characteristics of the athlete's psycho physiological allow the achievement of the best performances in close relation to circadian rhythms (L.Halson, 2014; Shapiro CM., 1981; Fundation, 2006; Leeder J, 2012). The request for maximum engagement in the morning, afternoon or night is, however, also influenced by particular chronotypes athletes, so, there may be deviations in physiological conditions, including body temperature, depending on which is oriented in the morning "Morningness" or afternoon "Eveningness" (Machado FS, 2015; Thun E, 2015; Rae DE, 2015; Lavoie JM, 1986).

Each sport, however, has its consolidated hourly characterization, consequently, the athletes, since the regional championships get adapted to the competition. Then, circadian rhythms permit the body to carry out its activities throughout the day's activities and to recover overnight. The recovery, not only influence the general condition of health, but is also particularly important for top athletes, who have to handle high loads of training during the day.

A period of tapering with individual variability, consisting of a balance of adequate volume / intensity of the competitive goals, will undergo to every athlete in order to maximize the training effect before the Olympic Competition (Smith DJ, 2002; ECSS, 2007; Waterhouse J,

2007; Al, 2001; I, 2012; Padilla, 2003; Mujika, 2007). Both quantity and quality of sleep are the key factor in the recovery. Researchers study sleep as an object of special interest during the last years (Chennaoui M., 2016). Sleep is an extremely complex process, governed by physiological and behavioral factors, which has two primary states: REM (rapid eye movement) and NREM (non-rapid eye movement). NREM sleep is divided into four further stages which characterize the progressive depth of sleep. It was hypothesized that the effective recovery for athletes occurs in the deeper phases, for the simultaneous activation of growth hormone, as well as the reduction of deep phases both in connection with a reduction of the performance (Gangwisch, 2014). Sleep duration in healthy people in America is between 6-8 hours during the week and on holidays 7.4h (L Citi, 2010), while recent studies have investigated the duration of sleep in athletes, estimating it in 8h36min; in contrast, it was noted that the duration longer in bed is characterized by a higher latency, ie 18.2 min to fall asleep (Horne JA, 1976).

Recent evidence has shown that the reduction of sleep for less than 6 hours for 4 consecutive nights or more will have a significant effect on athletic maximal and sub-maximal performance (Roepke SE, 2010). Impairment of sleep can affect learning, memory and cognitive aspects, in addition to increasing the perception of pain and effort with strong influences also on mood and appetite; not less, a reduction in the loss of motivation. Finally, also interferences in the glucose metabolism were demonstrated, in immune function and in the variability of cardiac function (C., 2008), also, it has been showed that a prolonged sleep deprivation is associated with an increase in blood pressure and heart rate at rest and it is the cause of hypertension (Silva A, 2010).

The timetable of the Rio 2016 Games for Swimming, needed adjustment to the circadian rhythms, with a shift of the light-wake cycle of about 3.5h, to start the recovery not before 02:00. This choice of schedules could then result in a decrease of sleep, affecting the anatomical, psychological and physiological which are the key points of the highest performance in the high-level swimming (Léger, 2014; Nédélec M, 2012).

Some factors can positively influence and intervene in processes, facilitating the restoration of the correct sleep-wake cycle, both in the immediate function Jet-Lag effect of the early days of the time shift in the week of competitions (Eirunn Thun, 2015). Among these, nutrition has a primary function, combined with behaviors such as reducing latency to bed, the absence of noise and light in the morning, additional period of rest after lunch, about 30min (Sinnerton S, 1992), whereas in the pre-competition periods athletes who have a lower perception of psycho-physical stress have a better mood and a better preparation for achievement (Dunlap JC, 2004). However, the effect of variation of the circadian rhythms, in addition to a phase of high competition, is a factor which may cause the further growth of an already strongly present disorder in athletes (Turner, 2016).

Proper nutrition promotes sleep, with the use of diets rich in tryptophan, which is the precursor of serotonin and melatonin, the sleep-wake rhythm controls (Al, 2001). Although melatonin may be obtained from nutrition, while its integration is associated with a limitation of the latency in bed that does not seem to facilitate the NREM sleep of the deeper stages (Sinnerton S, 1992).These diets, if not properly selected, can produce alterations in the Heart Rate Variability (HRV), where its study in Athletes has been

considered a valuable tool to investigate changes related to training, performance, fitness and recovery (Turner, 2016).

Overall, measures of HRV can be divided into three classes: the time domain, frequency domain a non-linear. In the frequency domain three different main spectral components are distinguished: Very Low Frequency (VLF), Low Frequency (LF) and High Frequency (HF). The HF are related to the cardiac vagal influence and represent the parasympathetic activity and the LF reflects baroreflex activity rather than sympathetic activity (Plews DJ, 2013) (Koening J, 2014) (Casadei B, 1995). HRV is in turn influenced by sleep with high levels of correlation between the low and high frequency (HF / LF), which demonstrates that the activation of the sympathetic system is caused by periods of sleep deprivation (Casadei B, 1995). Other studies with athletes and swimmers found changes in fatigue positive related to changes in HF and negatively related to LF (Koening J, 2014).

Performances in high-level competitions are then conditioned by many aspects, although marginal, whose combination may lead to a temporary overload condition: Functional Overreaching, that in the absence of adequate and complete recovery can become Non-Functional Overreaching and manifesting similar symptoms as Overtraining that leads to a decrease of the performance (ROMAIN MEEUSEN, 2006).

Therefore, given the interest of the various Team to optimize the performance, we analyzed sleep quality (SQ), the heart rate variability (HRV), the resting heart rate (HRR) and the total alteration of the index ' humor (TMD), during a week of time programming based on the Olympic program at the Swimming Rio2016 and its possible effects on the state of overreaching.

Methods

Participants

Three male swimmers (21 ± 1), qualified in the sprint races for the Olympic Games 2016 in Rio, were monitored during a week of night training sessions with the same time trial of the semi-finals and Olympic finals. The sleep-wake phases have been regulated with a beginning of the sleep phase at 02.30, wake up at 10:30 am, workouts in the pool respectively to 12.00 and 22:00 (second session in water) and 16.00 in the gym, while breakfast times, lunch and dinner at 11.00 (brunch type), at 18.00 and at 01.30 hours.

Design

The diet was varied as a function of a total intake of approximately 3500 kcal distributed to 30% at breakfast, 45% at lunch, and 25% at dinner. The composition of macronutrients was indicatively of 50% carbohydrates, 30% protein and 20% fat, with the possibility of varying these last two percentages, depending on the psycho-physical athlete's daily engagement. Athletes were monitored while sleeping for quality assessments (QMS), in which the total time in bed ratio was calculated using actigraphy (SenseWear, USA BodyMedia).

Measures

Athletes were monitored in the two days before the start of the protocol (T0) and in the following days, respectively, after 1, 3, 5 days (T1, T2, T3). The resting heart rate (HRR) and cardiac variability (HRV) were measured at awakening (Minicardio, Hosand - Italy). All athletes have responded to an "Eveningness / Morningness" questionnaire in relation to the chronotype profile (25). The evaluation of the mood disorder using the "Total Mood Disturbance" (TMD) has been made before and after a week of nightly workout. Nutrition has been specially adapted to allow proper integration and contribute to the maintenance of the quality of sleep. For each variable (mean and SD) we performed a univariate ANOVA with time factor (T0-T1-T2-Y3) to compare the significant effects between the individual sessions. At the same time we have run a t-test to check for any differences of TMD (at the beginning and at the end of the protocol). The level of significance was set at $p < 0.05$ using SPSS 15.0 Software.

Results

The Univariate ANOVA showed significant differences in the periods under analysis (T0-T1-T2-T3 -T4) for Very Low Frequencies "Very Low Frequency" ($F = 9.481$ - $p = 0.002$), low frequency "Low Frequency" ($F = 6.603$ - $p = 0.007$); high frequency "High Frequency" ($F = 9.209$ - $p = 0.002$) and SQ ($F = 19.189$ - $p < 0.0001$). Conversely, the ANOVA showed no significant effect on the HRR, ($F = 0.817$ - $P = 0.542$). Finally, the TMD has been very low at the start (5.50 ± 3.51 TMD), respect (81.00 ± 18.90 TMD) that recorded during the last session ($p = 0.031$).

Discussion

This study has examined the effects of a week of activity following the schedules established for the swimming competitions of the Olympic Games in Rio, with special attention to the athletes who aim at the semifinals and final, and therefore subject to several days to a postponement of the time program of the day, with a variation of the sleep-wake circadian rhythm cycle. The data suggest that the time shift with the simulation of the race late at night tends to affect the synchronization of the circadian rhythms, compromising the physiological and psychological conditions of athletes. The main results showed that there are effects on HRV, SQ and TMD.

The sleep detected is less than the required physiological limit (Gangwisch, 2014) and above the levels of partial deprivation alert (L Citi, 2010), starting from the second day of the protocol.

Similar results were reported in a study that included a partial deprivation of sleep for four days to 2.5h, with a mood disturbance and an increase in depression, tension, confusion, fatigue, anger, and a decrease in strength (Kuipers, 1988; Machado FS, 2015; Morgan, 1988) (31).

Increase in sleep disturbances, fatigue and tiredness, as well as alterations of the autonomic nervous system are present in 82% of the athletes before competition and seem to be treated as a state of overreaching in the short term even in swimmers (Ben Rattray, 2015; Hopkins, 2000); however, only 59% of the sports team is currently focused on this issue, adopting specific strategies (Elise Facer-Childs, 2015).

The resting heart rates, while not significant, have shown an increase, calling attention to a further trend to be taken into account, especially when used by the coach as a marker of the intensity of training.

The trend shows a progressive alteration of the heart rate variability and, in turn, a better quality of sleep after the fourth day, however, not sufficient to restore the previous physiological parameters. Probably, further behaviors and activities can limit the effects noted, such as to use a nutrition that provides easily digestible food before the last evening meal, so as to promote sleep, avoiding refined foods, added salt, sweetened beverages and foods cooked at high temperatures, baked and fried (Benloucif S, 2004).

At the end, the time shift has been shown to have a significant effect on the psychological and physiological variables observed, indicating potential effects on the behavior of the athletes on the second day. In order to reduce such impact, greater emphasis must be placed on the identification of nutritional needs and sleep of top swimmers and is also suggested the use of additional forms of relax such as massage, compression or stretching which, while not being supported by solid evidence, could facilitate the athlete's relaxation (A.Cappaert, 1999).

Conclusion

Therefore, to limit the effects of a change induced circadian rhythms, a proper athlete's education seems to be particularly effective with particular emphasis to the habits, behavior and compliance with the conditions favorable to a sleep with less latency, increased quantity and quality, especially in the deeper phases (L.Halson, 2014) . Special tips can be reported ((Ben Rattray, 2015; Rae DE, 2015; Turner, 2016; C., 2008), namely:

1. Provide for proper sleep hygiene including adequate behaviors and eliminate distractions.
2. Reduce the latency time in bed and avoid premature awakenings eliminating any source of light or sound, in an environment kept at 18/19 ° C.
3. Avoid bedding or clothing that may cause a temperature rise of the night.
4. Predict the hourly habits sleep / wake up very accurate in the previous months with a sleep duration of no less than 7h
5. Avoid the use of computer screens, tablets or smartphones in the hour before sleep, preferring a book.
6. Remove the table alarm clock.
7. Provide relaxation techniques such as visualization, deep breathing or meditation
8. Provide a nap after lunch and no later than early afternoon, no more than 30 minutes
9. Provide hydration based on low fixed residue water during the day, but limit the use of drinks late in the evening, to reduce the nighttime interruptions because of the need to urinate.
10. Eliminate drinks with caffeine or similar substances and energy.
11. Provide for an evening diet rich in high-glycemic carbohydrates to replenish muscle glycogen combined with the tryptophan-rich foods (1g).
12. Limiting supplements containing herbs (eg. Valerian) which could have potential contaminants detectable anti-doping controls.

13. Use supplements of BCAA, in such a way as to not overload the liver from a metabolic point of view and at the same time reconstitute the muscle fibers.
14. Use condiments based on turmeric, black pepper and ginger, in order to facilitate the digestive process.
15. After each training (30 minutes) prefer drinking fruit and vegetable extracts and eat dried fruits such as almonds and walnuts.

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