

Listening to Music Affects Diurnal Variation in Muscle Power Output

Authors

H. Chtourou^{1,2}, A. Chaouachi¹, O. Hammouda¹, K. Chamari^{1,3}, N. Souissi^{1,3}

Affiliations

¹ Research Laboratory "Sports Performance Optimization" National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia

² Research Unit, High Institute of Sport and Physical Education, Sfax, Tunisia

³ High Institute of Sport and Physical Education, Ksar-Saïd, Manouba University, Tunisia

Key words

- circadian rhythm
- muscle power
- warm-up
- music

Abstract



The purpose of this investigation was to assess the effects of listening to music while warming-up on the diurnal variations of power output during the Wingate test. 12 physical education students underwent four Wingate tests at 07:00 and 17:00 h, after 10 min of warm-up with and without listening to music. The warm-up consisted of 10 min of pedalling at a constant pace of 60 rpm against a light load of 1 kg. During the Wingate test, peak and mean power were measured. The main finding was that peak and mean power improved from morning to afternoon

after no music warm-up ($p < 0.001$ and $p < 0.01$, respectively). These diurnal variations disappeared for mean power and persisted with an attenuated morning-evening difference ($p < 0.05$) for peak power after music warm-up. Moreover, peak and mean power were significantly higher after music than no music warm-up during the two times of testing. Thus, as it is a legal method and an additional aid, music should be used during warm-up before performing activities requiring powerful lower limbs' muscles contractions, especially in the morning competitive events.

Introduction



During a 400-m time trial, Simpson and Karageorghis [17] showed that listening to music results in better performance than a no-music control. Moreover, Eliakim et al. [8] found that following a warm-up in which music was heard; peak power (PP) during the Wingate test was significantly higher in adolescent volleyball players (10.7 ± 0.3 vs. 11.1 ± 0.3 W/kg, $p < 0.05$, without and with music, respectively). However, these authors found that music had no significant effect on the mean power (MP). In addition, this auditory stimulus has been shown to be effective in reducing perceived levels of exertion (RPE; [21]) enhancing arousal levels after long duration exercise [11] and facilitating motor coordination during short-term maximal exercise [17]. In this context, Eliakim et al. [8] showed that RPE scores after the Wingate test were unaffected by listening to the music during the warm-up. Furthermore, it has been shown that PP and MP during the Wingate test fluctuate with time-of-day, with an acrophase (peak) at 17:24±00:36 h and 18:00±01:01 h (mean±SD) respectively, and an amplitude of 7.6±0.8% and 11.3±1.1%

(mean±SD), respectively [18]. The fact that power during a 30-s Wingate test was lower in the morning raises the question of what limits performance at this time-of-day. In this context, since this test requires a strong level of motivation, Souissi et al. [18] suggested that the lower level of motivation in the morning could, in part, be responsible for such diurnal variation. Moreover, Lericollais et al. [13] suggested that a pacing-strategy effect (i.e., the strategies used by a subject to distribute work and energy throughout an exercise task) could also explain the lower performances observed in the morning. As the music's motivational effects have been linked to increases in individual perceptions of self-esteem and sense of confidence, enhancing arousal [11] and facilitating motor coordination [17], the question then arises to determine if listening to music during warm-up can lead to similar or different improvements in short term exercise performances in the morning and evening. Thus, the aim of the present investigation was to study the diurnal fluctuations during the Wingate test's performance while examining if warm-up with music helps athletes to overcome the morning alteration of power output. The

accepted after revision
July 05, 2011

Bibliography

DOI <http://dx.doi.org/10.1055/s-0031-1284398>
Published online:
December 1, 2011
Int J Sports Med 2012; 33:
43–47 © Georg Thieme
Verlag KG Stuttgart · New York
ISSN 0172-4622

Correspondence

Dr. Nizar Souissi, MCU
Research Laboratory "Sports
Performance Optimization"
National Center of Medicine
and Science in Sports (CNMSS)
Ave Med Ali Akid
1004 Tunis
Tunisia
Tel.: +216/96/818 633
Fax: +216/70/97 89
n_souissi@yahoo.fr

morning nadir of performances correlates with the lower levels of mood states, fatigue (i.e., loss of desire or ability to perform the test), and subjective sleepiness (i.e., desire to sleep) [19] at this time-of-day. Since music can be used as a tool to 'psych up' in preparation for performance (arousal regulation), shift intentional focus (association/dissociation), boost self-efficacy and encourage psychological skills usage (e.g. mental imagery [5], we hypothesized that music during warm-up reduces the diurnal variations of short-term maximal performances by a greater ergogenic effect in the morning.

Methods



Subjects

Twelve male physical education students (22.4 ± 1.7 yrs, 176.7 ± 5.8 cm and 72.5 ± 6.5 kg) voluntarily participated in this study. Prior to commencing the study, all subjects were informed about the experimental procedures and the possible risks and discomforts associated with the study. Each subject signed a written informed consent prior to participation. The study was conducted in accordance with the Declaration of Helsinki as well as the ethical standards of the IJSM [9]. The protocol was fully approved by the Clinical Research Ethics Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS) before the commencement of the assessments. Subjects were categorized either as "moderately morning type" ($n=4$) or as "neither type" ($n=8$), on the basis of their answers to the Horne and Östberg's [10] self-assessment questionnaire.

Experimental design

During the week before the experiment, all subjects came to the laboratory several times and at different hours of the day to become fully familiarized with the procedure and tests involved so as to minimize learning effects during the experiment. Then the subjects performed four experimental test sessions in a random order: 2 in the morning (07:00–09:00h) and 2 in the evening (17:00–19:00h) with either a 10 min warm-up with music (MWU) or 10 min warm-up without music (NMWU). The experimental test sessions were conducted as follows: 10 min warm-up followed by 30 s Wingate test. During the warm-up, subjects pedalled at a constant pace of 60 rpm against a light load of one kilogram. Immediately after the warm-up, subjects started the 30 s Wingate test.

In the night preceding each test session, subjects were asked to keep to their usual sleeping habits, with a minimum of 7 h sleep. Moreover, participants were requested to maintain their habitual physical activity and to avoid strenuous activity on the day before each test session. Before the morning test session, only one glass (15 to 20 cl) of water was allowed, to avoid postprandial thermogenesis effects. After the morning session, unrestricted food intake was allowed. Before the evening test session, they had the same standard isocaloric meal at 12:00h, which was concluded at the latest 5 h before the test. After that meal, only water was allowed *ad libitum*.

Music protocol

In order to mimic competitive conditions, music was played only during the warm-up. Due to the exercise type (high-intensity), high tempo music (> 120 to 140 bpm) was chosen for the study. The selection's criteria were based on the five recommendations of Karageorghis et al. [12]. Music was played from recorded

cassette tapes through personal headphones. In the no-music condition, headphones were worn but no sound was played. The music was switched off after the 10-min warm-up period.

Rating of Perceived Exertion Scale (RPE)

Rate of perceived exertion (RPE) was determined using the Borg scale [6] at the end of the warm-up (endWU) and the Wingate test (endWin). The RPE scale allows participants to give a subjective exertion rating for the physical task. The scale presents a 15-point scale ranging from 6 (very very light) to 20 (very very hard). The higher the RPE score, the higher the rating of perceived exertion. The RPE scale is a reliable indicator of physical discomfort, has sound psychometric properties and is strongly correlated with several other physiological measures of exertion [6].

Wingate test

The Wingate test was conducted on a friction-loaded cycle ergometer (Monark 894^E, Stockholm, Sweden) interfaced with a microcomputer. This test consisted of a 30-s maximal sprint against a constant resistance related to body mass ($0.087 \text{ kg} \cdot \text{kg}^{-1}$ body mass) as proposed by Bar-Or [3]. The test began from a rolling start, at 60 rpm against minimal resistance (weight basket supported). When a constant pedal rate of 60 rpm was achieved, a countdown of "3–2–1-go!" was given by the experimenter. At the start signal, subjects were instructed to pedal as fast as they could during 30 s. During the test, they had to remain seated and were strongly encouraged to reach the maximal pedalling rate as quickly as possible. The peak power output (PP) and the mean power (MP), corresponding to the ratio between total work done and time to do it (i.e., 30 s), were recorded at the end of the test.

Statistical analysis

Statistical tests were processed using STATISTICA Software (StatSoft, France). Mean and SD (standard deviation) values were calculated for each variable. The Shapiro-Wilk *W*-test of normality revealed that the data were normally distributed. Once the assumption of normality was confirmed, parametric tests were performed. A two-way ANOVA (2 [music] $\times$ 2 [time-of-day]) with repeated measures on both factors was used to analyze the Wingate test performance data. RPE data were analyzed using a three factors ANOVA (2 [music] $\times$ 2 [time-of-day] $\times$ 2 [exercise]) with repeated measures on the three factors. When appropriate, the Least Significant Different (LSD) post-hoc test was used for multiple pair-wise comparisons. Differences in amplitude of the diurnal variations between the two experimental conditions were analyzed using independent samples of *t*-tests. A probability level of 0.05 was selected as the criterion for statistical significance.

Results



Muscle power (PP and MP) during the Wingate test

Fig. 1, 2 show the mean values of PP and MP recorded at 07:00 and 17:00h during MWU and NMWU. There was a significant main effect for time-of-day ($F_{(1,11)}=21.31$, $p<0.001$ and $F_{(1,11)}=8.81$, $p<0.05$ for PP and MP, respectively) and music ($F_{(1,11)}=10.44$, $p<0.01$ and $F_{(1,11)}=11.60$, $p<0.01$ for PP and MP, respectively). Likewise, there was a significant music $\times$ time-of-day interaction ($F_{(1,11)}=5.97$, $p<0.05$ and $F_{(1,11)}=6.63$, $p<0.05$ for

PP and MP respectively). The *post-hoc* test revealed that muscle power was significantly higher in the evening than in the morning in NMWU for PP ($p<0.001$) and MP ($p<0.01$) (○ Fig. 1, 2). These diurnal variations were blunted for MP (○ Fig. 2) and reduced for PP ($p<0.01$) (○ Fig. 1) by an attenuated morning-evening difference after the MWU condition ($p<0.05$) (○ Table 2). In addition, power output (PP and MP) were significantly higher during MWU than NMWU at the two times of testing ($p<0.001$ in the morning and $p<0.05$ in the evening) (○ Fig. 1, 2). However, there was no significant difference between morning MWU and evening NMWU conditions.

Rate of perceived exertion (RPE)

○ Table 1 shows the mean values of RPE scores recorded in the morning and the evening during MWU and NMWU. There was a significant main effect for exercise ($F_{(1,11)}=124.46$; $p<0.001$) and music ($F_{(1,11)}=7.96$; $p<0.05$). However, the time-of-day effect and the music $\times$ time-of-day $\times$ exercise interaction were not significant ($F_{(1,11)}=0.25$; $p>0.05$ and $F_{(1,11)}=1.11$; $p>0.05$, respectively). RPE scores were significantly higher after the Wingate test in comparison with after the warm-up ($p<0.001$) at the two times of testing. Moreover, RPE scores were significantly higher during MWU than NMWU conditions in the morning after the warm-up ($p<0.05$) but in the morning and evening after the Wingate test ($p<0.01$).

Discussion

The aim of this study was to examine the effects of warm-up while listening to music on the diurnal fluctuations of muscle power. The results showed that peak and mean powers increased following music warm-up in comparison with no music warm-up. Moreover, music during warm-up modified the magnitude of the diurnal variations of muscle power during the Wingate test due to higher increase in performance in the morning (i.e., MP was independent of time-of-day after MWU and the morning-evening difference was attenuated for PP).

Diurnal variations after the warm-up without music

Concerning the parameters recorded during the Wingate test, in agreement with previous reports, PP and MP were higher in the evening compared to the morning, with gains of 5.3 and 3.3%, respectively. Until now, the exact underlying mechanisms of these diurnal fluctuations are not known, but some authors [4, 14, 20] have hypothesized a causal link between the temporal fluctuations in core temperature and the diurnal variations of power output. The increase in body temperature in the evening hours may produce an increase in the extensibility of connective tissue and in the conduction velocity of action potentials, a decline in muscle viscosity and an enhancement of metabolic reaction [18]. These diurnal modifications could explain better motor coordination in the evening compared to the morning and an increase in the subject's ability to adopt high pedal rates and thus produce higher power output in the evening [13]. However, others factors can be evoked to explain the diurnal variations in muscle power. Lericollais et al. [13] and Souissi et al. [18] have hypothesized that the diurnal fluctuations in power output during the Wingate test could partly be attributed to the daily variations in motivation. In fact, higher evening motivation and arousal [13, 16] could contribute to the higher muscle power observed at this time.

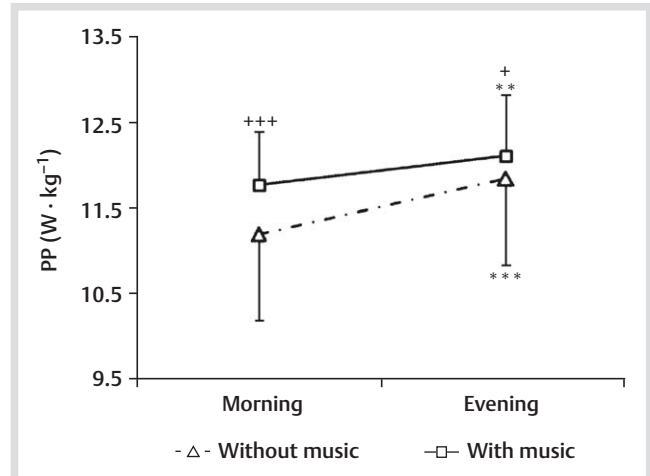


Fig. 1 Mean $\pm$ SD for peak power (PP) recorded at 07:00 and 17:00 h during the two experimental conditions. **, ***: significant difference between 07:00 and 17:00 h at the level of $p<0.01$ and $p<0.001$ respectively. +, +++; Significant differences between NMWU and MWU at the level of $p<0.05$ and $p<0.001$ respectively.

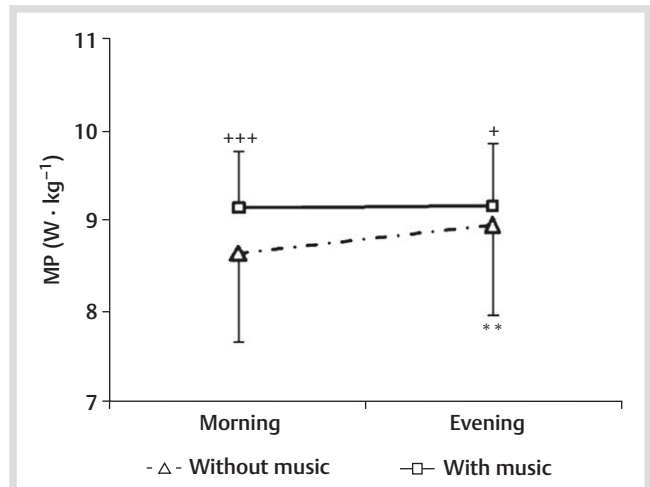


Fig. 2 Mean $\pm$ SD for mean power (MP) recorded at 07:00 and 17:00 h during the two experimental conditions. **: significant difference between 07:00 and 17:00 h at the level of $p<0.01$. +, +++; Significant differences between NMWU and MWU at the level of $p<0.05$ and $p<0.001$ respectively.

Table 1 RPE scores (mean $\pm$ SD) at 07:00 and 17:00 h after the music and the no music protocols at the end of the warm-up (endWU) and after the Wingate test (endWi).

	Without music		With music	
	07:00 h	17:00 h	07:00 h	17:00 h
endWU	9.50 $\pm$ 1.88	9.33 $\pm$ 1.97	10.33 $\pm$ 2.35+	9.58 $\pm$ 2.11
endWi	16.25 $\pm$ 1.76	16.33 $\pm$ 1.67	17.42 $\pm$ 1.56++	17.58 $\pm$ 1.38++

+, ++: Significant differences between the two experimental conditions at the level of $p<0.05$ and $p<0.01$ respectively

Table 2 Morning-evening differences in power output (mean $\pm$ SD) after the two experimental conditions.

	Without music	With music	p value
PP (%)	5.34 $\pm$ 3.52	2.73 $\pm$ 3.16	$p<0.05$
MP (%)	3.32 $\pm$ 3.19	0.13 $\pm$ 2.47	$p<0.05$

PP: peak power; MP: mean power

Music effects

The present study results indicated that power output increased after music warm-up in comparison with no music warm-up especially in the morning hours. These findings are in agreement with those of previous studies [8, 17]. Indeed, Simpson and Karageorghis [17] showed that music might exert an ergogenic effect during a 400-m time trial and thus increase athlete's performance. Likewise, Eliakim et al. [8] observed that warm-up with music increased the subsequent peak power during the Wingate test (10.7 ± 0.3 vs $11.1 \pm 0.3 \text{ W} \cdot \text{kg}^{-1}$) in highly trained adolescent volleyball players. However, the authors did not find any music effect on the mean power during this test. Nevertheless, Pujol and Langenfeld [16] showed that performances during the Wingate test are independent of music. The discrepancies between these findings might be due to the difference between subjects' fitness levels. In fact, previous reports have demonstrated that music had greater ergogenic effects in untrained participants or during the initial stages of a training program, and that the influence of music on performances decreased markedly with increased fitness levels [7, 8]. Moreover, these discrepancies could also be due to the use of music during the exercise or during the warm-up [17].

The present results also showed that the diurnal variations of muscle power during the Wingate test were modified (i.e., no time-of-day effect for mean power, after music warm-up and attenuated morning-evening difference for peak power) after listening to the music during the warm-up due to higher improvement in performances at 07:00h. As this is the first study examining the effect of music on the diurnal variations of short-term maximal performances, it is difficult to compare these results with existing studies in the literature and to explain this more important ergogenic effect. However, as mentioned in the introduction, the batyphase of performances correlates with lower levels of mood status, fatigue (i.e., loss of desire or ability to perform the test), and subjective sleepiness (i.e., desire to sleep) [19] in the morning. In addition, Lericollais et al. [13] suggested that a pacing-strategy effect (i.e., the strategies used by a subject to distribute work and energy throughout an exercise task) could also explain the lower power output observed in the morning hours. Thus, during morning's short-term high intensity exercise, subjects would aim to be more psyched up, may wish to dissociate from unpleasant exertion induced sensations, feel confident and employ appropriate psychological coping strategies. In this context, it has to be emphasized that the subjects pacing strategy and especially the rating of perceived exertion during exhausting exercise are dependent on emotions [2]. The literature has reported that the music's motivational effects have been linked to increases in individual perceptions of self-esteem and sense of confidence [11]. Moreover, music has been shown to be effective in reducing perceived exertion (i.e., during submaximal exercise) [21], enhancing arousal [11] and facilitating motor coordination [17]. Although speculative, it is possible that the music could have induced an ergogenic effect that was more important in the morning.

Morning RPE scores were higher for music warm-up than no music warm-up. The current data are in agreement with previous findings [8] in which higher RPE scores were observed after music warm-up. Despite the fact that warm-up intensity was monitored and standardized in the present study; these findings suggest the possibility of higher warm-up intensity while listening to music. Some support for this suggestion can be found in the post-trial comments made in the present study where some

subjects felt that they "wanted to pedal faster in the warm-up because of the music" in the two MWU conditions. However, since the effort during the warm-up in both conditions was perceived as very easy (mean RPE~10), conclusions regarding this difference are probably negligible. After the Wingate test, in agreement with Atkinson et al. [1] (i.e., during a 10-km cycling time trial), the RPE scores were higher after music warm-up than no music warm-up at the two times of testing. However, Eliakim et al. [8] were unable to show any differences between music and no music warm-up in RPE scores. The disparity between these results could be due the fact that RPE values are influenced by the situation in which the exercise is performed and by the disposition of the exerciser. In fact, situational and dispositional factors such as personality, motivation, and attention can influence the perception of exertion during exercise [15].

In light of the present study's findings and those of previous research, it is apparent that music during warm-up before a Wingate test seems to be effective to improve muscular power especially in the morning hours and to avoid the negative impact of time-of-day on power output. In fact, listening to music during warm-up before a morning Wingate test can improve typically poor morning performances to the same or even higher level as their normal daily peaks typically observed in the evening without listening to music. Thus, as a clear trend is emerging in the literature which suggests that music is a genuine ergogenic aid, music should be heard during warm-up before performing activities requiring powerful muscular contractions, especially when competitions are scheduled in the morning hours. This is an important point for coaches and it may benefit athletes involved in sports requiring powerful lower-extremity muscular contractions because it implies that all warm-ups before a competition must be performed taking into consideration the effects of music and time-of-day of the competitive events. However, it would be useful to have more physiological (e.g., blood lactate) and psychological (e.g., motivation, personality) data to complement the present study's findings and to reveal the physiological and psychological mechanisms that underlie the effect of this auditory stimuli on the diurnal variations of power output during a short-term powerful exercise.

Acknowledgements



The authors wish to express their sincere gratitude to all the participants for their maximal effort and cooperation. This study was financially supported by the Ministry of Higher Teaching and Scientific Research, Tunisia.

References

- 1 Atkinson G, Wilson D, Eubank M. Effects of music on work-rate distribution during a cycling time trial. *Int J Sports Med* 2004; 25: 611–615
- 2 Baron B, Moullan F, Deruelle F, Noakes TD. The role of emotions on pacing strategies and performance in middle and long duration sport events. *Br J Sports Med* 2011; 45: 511–517
- 3 Bar-Or O. The Wingate Anaerobic Test. An update on methodology, reliability and validity. *Sports Med* 1987; 4: 381–394
- 4 Bernard T, Giacomoni M, Gavarry O, Seymat M, Falgairette G. Time-of-day effects in maximal anaerobic leg exercise. *Eur J Appl Physiol* 1998; 77: 133–138
- 5 Bishop D, Karageorghis C, Loizou G. A grounded theory of young tennis players' use of music to manipulate emotional state. *J Sport Exerc Psychol* 2007; 29: 584–607
- 6 Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14: 377–381

- 7 De Bourdeaudhuij I, Crombez G, Deforche B, Vinaimont F, Debode P, Bouckaert J. Effects of distraction on treadmill running time in severely obese children and adolescents. *Int J Obes Relat Metab Disord* 2002; 26: 1023–1029
- 8 Eliakim M, Meckel Y, Nemet D, Eliakim A. The effect of music during warm-up on consecutive anaerobic performance in elite adolescent volleyball players. *Int J Sports Med* 2007; 28: 321–325
- 9 Harriss DJ, Atkinson G. Update – Ethical Standards in Sport and Exercise Science Research. *Int J Sports Med* 2011; 32: 819–821
- 10 Horne JA, Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol* 1976; 4: 97–110
- 11 Karageorghis CI, Priest DL, Terry PC, Chatzisarantis NLD, Lane AM. Redesign and initial validation of an instrument to assess the motivational qualities of music in exercise: The Brunel Music Rating Inventory-2. *J Sports Sci* 2006; 24: 899–909
- 12 Karageorghis CI, Terry PC. The psychophysical effect of music in sport and exercise: a review. *J Sport Behav* 1997; 20: 54–68
- 13 Lericollais R, Gauthier A, Bessot N, Sesboüé B, Davenne D. Time-of-day effects on fatigue during a standard anaerobic test in well-trained cyclists. *Chronobiol Int* 2009; 26: 1622–1635
- 14 Melhim AF. Investigation of circadian rhythms in peak power and mean power of female physical education students. *Int J Sports Med* 1993; 14: 303–306
- 15 Morgan WP. Psychological components of effort sense. *Med Sci Sports Exerc* 1994; 26: 1071–1077
- 16 Pujol TJ, Langenfeld ME. Influence of music on Wingate Anaerobic Test performance. *Percept Mot Skills* 1999; 88: 292–296
- 17 Simpson SD, Karageorghis CI. The effects of synchronous music on 400-m sprint performance. *J Sports Sci* 2006; 24: 1095–1102
- 18 Souissi N, Gauthier A, Sesboüé B, Larue J, Davenne D. Circadian rhythms in two types of anaerobic cycle leg exercise: Force-velocity and 30-s Wingate tests. *Int J Sports Med* 2004; 25: 14–19
- 19 Van Dongen HPA, Dinges DF. Circadian rhythms in fatigue, alertness, and performance. In: Kryger MH, Roth T, Dement DC. (eds.). *Principles and Practice of Sleep Medicine* Philadelphia WB Saunders, 2000
- 20 Waterhouse J, Drust B, Weinert D, Edwards B, Gregson W, Atkinson G, Kao S, Aizawa S, Reilly T. The circadian rhythm of core temperature: Origin and some implications for exercise performance. *Chronobiol Int* 2005; 22: 207–225
- 21 Yamashita S, Iwai K. Effects of music during exercise on RPE, heart rate and the autonomic nervous system. *J Sports Med Phys Fitness* 2006; 46: 425–430