

The effects of music and visual stress on testosterone and cortisol in men and women

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Submitted: March 25, 2003

Accepted: April 29, 2003

Key words: **testosterone; cortisol; listening to music; visual stress; differences between the sexes**

Neuroendocrinol Lett 2003; 24(3/4):173-180 pii: NEL243403A04 Copyright © Neuroendocrinology Letters www.nel.edu

Abstract

OBJECTIVES: The aims of the present study were to examine sex-related differences in testosterone (T) and cortisol (C) changes with music listening and visual stress.

SETTING AND DESIGN: Saliva T and C concentrations were measured in 88 healthy college students (44 males and 44 females). These subjects were placed in one of 4 different conditions: (1) 30 min of listening to music, (2) 30 min of listening to music with visual stress (documentary film without sound including violent scenes), (3) 30 min of visual stress without music, and (4) 30 min of silence.

METHODS: All subjects provided two saliva samples, one collected before intervention and the other after intervention. T and C levels were assessed by radio immuno assay (RIA).

RESULTS: There was a significant difference between the sexes in the way music affected T. Music decreased T in males, whereas it increased T in females. As for C, no sex-related differences were found under any of the conditions studied. C decreased with music and increased under other conditions.

THE MAIN FINDINGS: Our data suggests that the effects of music and stress on T differ between males and females.

CONCLUSION: Further investigation is necessary to evaluate the relationships between music and other substances, the effect of degree of preference and hormonal changes not only during music listening but also during music plays and creation.

Abbreviations

T	testosterone
C	cortisol
POMS	Profile of Mood States
RIA	radio immuno assay
HPA axis	hypothalamus-pituitary-adrenal axis
ACTH	adrenocorticotrophic hormone
GnRH	gonadotropin-releasing hormone
LH	luteinizing hormone
CRH	corticotropin releasing hormone

Introduction

Psychological and physiological stress affects testosterone (T) and cortisol (C) levels in both sexes. Stress responses of the pituitary-gonadal axis demonstrate a distinguished perceptiveness.

Generally, C increases significantly in the presence of stress. With physical stress such as marathon [1, 2] bungee jumping [3], bicycle ergometer exercise [4], treadmill exercise [5], C increases significantly. Under psychosomatic and psychic stress, C increased in both sexes. Social stress increased the C level in both sexes [6, 7]. Hence, C increases in the presence of stress whether it is physical or mental.

Gender differences in human stress responses are less understood than those in experimental animals, despite some differences in hormonal responses, although stimuli in female and male subjects were reported. Some authors have reported sex-related differences in both the production and metabolism of C in healthy subjects [8–10]. It has also been reported that the magnitude of C responses to mental stress differs between males and females [11, 12]. However, according to several studies, there are sex-related differences in T responses to stress. T levels in males decrease under psychosomatic or psychic stress and even with the anticipation of stressful events, whereas T concentrations in females rise under these conditions [*e.g.*, 13, 14]. During and after prolonged submaximal exercise, T levels decreased in males and increased or remained unchanged in females [15]. Anticipation of a stressful event leads to a decreased T level in males and an increased T level in females [16, 17]. Even with psychosomatic or psychic stress, such as financial difficulties, dissatisfaction or watching stressful movies (dental surgery), T levels decrease in males and increase in females [17, 18].

It has been reported that music functions to ease stress responses psychologically, physiologically, and endocrinologically. It is well known that listening to music eases uneasiness [19, 20], depression, and fatigue [21, 22], changes mood [23–26], and suppresses pain [27–29]. However, some reports are available in which comparisons of music listening and other relaxation methods showed no difference in alleviation of anxiety, depression, and fatigue [21, 22] or reduction of heart rate [30, 31]. In addition, some authors have reported that there are differences in psychological and physiological responses among different genres of music (classicals, hard rock, “favorite music,” “relaxation music”) [32] and others have reported no such differences [33].

Listening to music for short periods of time could lower C regardless of the subject’s mental state [34, 35] and music significantly lowered [36–38] or suppressed C levels [39] even during surgery. Other papers reported that not only music listening but also music playing (playing percussion instruments) lowered C levels [40, 41]. In addition, there were studies that C responses differed by music experience [42, 43] and the subject’s preference [44]. However, so far the results are contradictory and there is no common tendency or universality for the relation between C and music category or preference. Yet judging from published research results, listening to one’s favorite music decreases C [45].

Contrary to C, quite a few investigations have been conducted on the relationship between music and T. Regarding musical ability and T, there is a high positive correlation between spatial cognitive ability and musical ability (talent) [46]. A high correlation is also found between spatial cognitive ability and T [47]. Furthermore, these correlations differ between males and females, *i.e.*, sex-related differences are present. Hasler [48] reported that male composers had relatively low T values, and that T values increased as musical ability increased in female composers.

On the other hand, only one report is available on sex-related differences in T responses associated with music playing or listening; in that report, a sex-related difference in T responses to music listening was shown [49]. Fukui [49] examined T value changes between before and after listening to a wide variety of music, including favorite music, pops, jazzes, and classical, in male and female students, and showed a sex-related difference. Specifically, T values decreased in males and increased in females after listened to music, regardless of genre. Interestingly, the sex-related difference in T changes with music listening was the same as the sex-related difference in stress responses.

Are the C and T responses to music listening the same as the responses to stress stimulation? The aims of the present study were to examine sex-related differences in T and C changes with music listening and visual stress. We hypothesized that C would decrease among both sexes during music listening, the reason being that music, unlike stress, is physiologically pleasant. Even when presented together with stress (images), C increase would be suppressed. Also, the T reactions would confirm prior research results wherein music and stress presented similar changes.

Materials and methods

88 college students, all in good health and none on medication, were recruited by a notice at a university (44 males: 22 music majors and 22 non-music majors, and 44 females: 21 music majors and 23 non-music majors, ages ranging 18 to 27 years, average age being 21 ± 2 years). Subjects were all volunteers without compensation. Both music majors and non-music majors were recruited bearing in mind published studies reporting that the length of music experience affected C responses [42, 43]. Only females claiming regular

menstrual cycles were selected. Females with a normal menstrual cycle of 28–32 days provided saliva samples on the 10th–13th and 22nd–27th days. Samples collected in the luteal (22 females) and follicular (22 females) phases were analyzed.

The experiments were conducted using a between-subject design. There were 11 males and 11 females in each of the 4 conditions rather than repeating that each time: (1) 30 min of listening to music (11 males, 11 females), (2) 30 min of visual stress with listening to music (documentary film without sound including violent scenes) (11 males, 11 females), (3) 30 min of visual stress without music (11 males, 11 females), and (4) 30 min of silence (11 males, 11 females). This allocation was conducted randomly so that all conditions had the same ratio of music majors and non-music majors and the same ratio of subjects in the follicular phase and those in the luteal phase (females only).

Directions were given to the male and female subjects by a male and female research assistant, respectively. Before signing the consent form, each subject was given an explanation about the procedures of the experiment but not informed of its goals. The experiment was carried out in a quiet laboratory at given hours (14:00 to 17:00), bearing in mind that T and C levels have been reported to undergo a diurnal variation in males and females [50–52]. Stimuli were given via audio speakers at the appropriate sound level (70–75 db). Each subject provided a 7 ml saliva sample at the beginning of experiment for baseline. Subsequently, they were given a questionnaire consisting of a psychological test based on a simplified form of the Profile of Mood States (POMS) [53], together with a rating scale table by which the subjects evaluated their preference in music. The POMS simplified and original forms indicated a high correlation ($\gamma = .95$) [53]. In POMS, subjects were asked to respond to words that reflected certain mood states (*e.g.*, sad). Total POMS scores obtained before and after stimulation in each of the four conditions.

Next, each stimulus (30 min) or silence was administered. After saliva was sampled again, the subjects were given a questionnaire again. Saliva was collected by holding a dental swab in the mouth for approximately 2 min. The saturated swab was placed in a capped plastic vial (Salivette, manufactured by Sarstedt). These samples were refrigerated at -20°C and sent to the laboratory. T and C levels (only free T and C) were determined by radio immuno assay (RIA) as described elsewhere [54]. The Coat-a-Count Kit (Diagnostic Products, Los Angeles, CA) was employed for the assay. The inter- and intra-assay coefficients of variation for T and C were 11.7% and 4.58%, respectively. Saliva T and C concentrations are highly correlated with serum concentrations [55] and represent the free and biologically active steroid fraction. Taking a saliva sample is a less invasive and less stressful procedure compared to drawing blood. At the end of session, the subjects were given a questionnaire about their experience, behavior, and preference in music.

The music stimulus used for the experiments was a sequence of five pieces of Japanese children's folk songs (WABI, FAIRLAND, NACL-1051) that were mellow with lyrical tunes and sung in English by Susan Osborn. The reasons for choosing this music were: 1) they were Japanese popular songs the subjects liked, and 2) because when the songs were sung in English, the subjects were expected not to be affected directly by the meaning of the words.

The visual stress stimulus used was a documentary film including riots, accidents, and war, entitled "The Horrible Incident Part 2" (Packin Video Inc.). Most scenes were cruel and inhuman. Stimulation with this film was expected to cause negative feelings.

Several separate analyses were performed. First, differences in the four conditions as well as sex, major, cycle, and hormone (C, T) and POMS changes were analyzed using repeated measures analysis of variance (ANOVA-R). When permitted by ANOVA-R, a post-hoc Fisher's PLSD was also performed. Second, to examine the relationship among changes over time in C, T, and POMS, percent changes were calculated relative to baseline values taken as 100, and Spearman correlation coefficients were calculated. Total POMS scores obtained before and after stimulation in each of the four conditions were analyzed by paired *t*-test.

Results

The mean \pm SE of T levels in the male and female subjects was 219 ± 39 pg/ml and 108 ± 21 pg/ml, respectively. In the male subjects, the effect of T change was significant ($F(1, 40)=4.242$, $p=.0460$), the effect of conditions was not significant ($p = \text{ns}$), and the effect of conditions-by-T change interaction was significant ($F(3, 40)=7.512$, $p=.0004$) (Figure 1). Post-hoc test revealed no significant difference between the music condition and the stress with music condition or the stress condition. In the female subjects, the effect of T changes was significant ($F(1, 40)=12.180$, $p=.0012$) (Figure 2), but the effect of conditions and conditions-by-T change interaction was not significant ($p=\text{ns}$). There were no significant effects from major in either sex and no significant effects from menstrual cycle in the females ($p=\text{ns}$).

In addition, since the music condition showed a sex-related difference in T changes, values after stimulation were calculated relative to a baseline taken as 100 and tested statistically. ANOVA was carried out for the music condition with sex and T value changes as variables. In the results, the effect of sex was significant ($F(1, 20)=19.882$, $p=.0012$); T decreased by 14% after stimulation in male subjects and increased by 21% in female subjects (Figure 3).

The mean \pm SE for C levels in the male and female subjects was $.30 \pm 13$ $\mu\text{g}/\text{dl}$ and $.31 \pm 08$ $\mu\text{g}/\text{dl}$, respectively. ANOVA-R revealed that, in the male subjects, the effect of C changes and the effect of condition were not significant ($p=\text{ns}$), and the effect of condition-by-C change interaction was significant ($F(3, 40)=5.334$, $p=.0035$) (Figure 4). In the female subjects, the effect

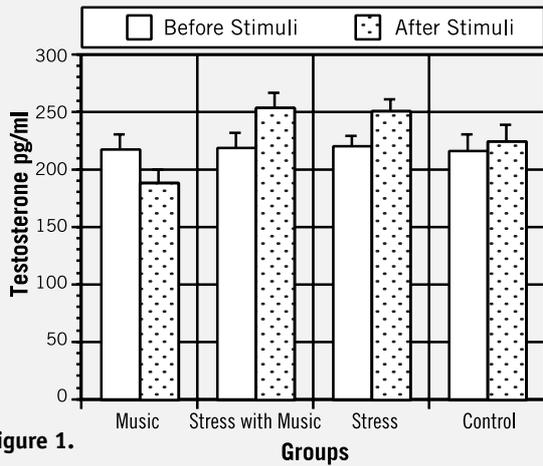


Figure 1.

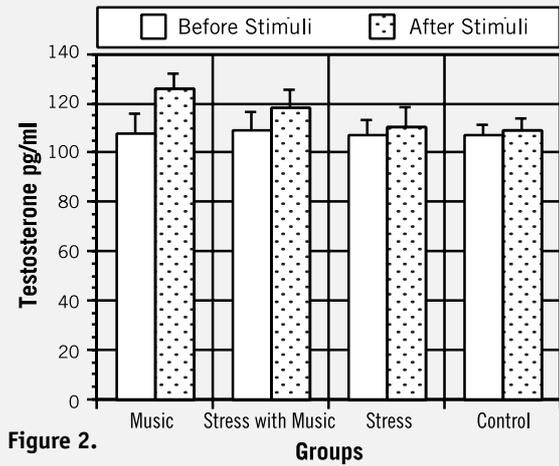


Figure 2.

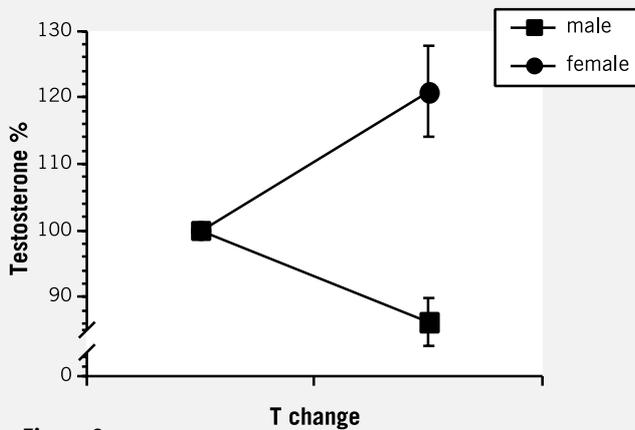


Figure 3.

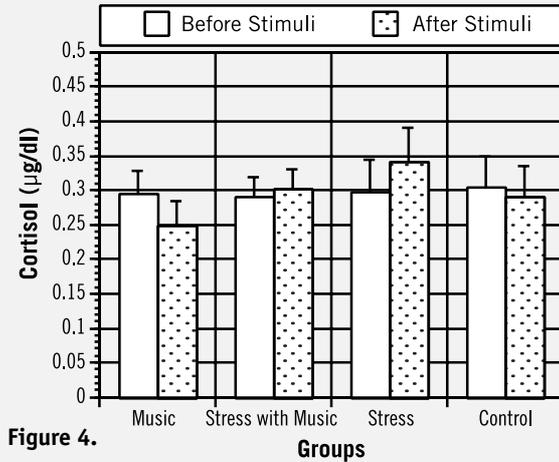


Figure 4.

Figure 1. T levels of 44 male subjects sampled at 30 min interval. ANOVA revealed that the main effect of T changes was significant ($F(1, 40)=4.242, p=.0460$). The effect of conditions was not significant ($p=ns$), but the effect of conditions-by-T change interactions was significant ($F(3, 40)=7.512, p=.0004$). A post-hoc test revealed no significant difference between the music condition and the stress with music condition or the stress condition.

Figure 2. T levels of 44 female subjects sampled at 30 min interval. ANOVA revealed that the effect of T changes was significant ($F(1, 40)=12.180, p=.0012$), but the effect of conditions and conditions-by-T change interactions was not significant ($p=ns$). There was also no significant effect from menstrual cycle ($p=ns$).

Figure 3. T changes (percentage change) of 22 subjects in the music condition shows primarily the effect of sex ($F(1,40)=12.180, p=.00012$). After stimulation, T decreased by 14% among male subjects and increased by 21% among female subjects.

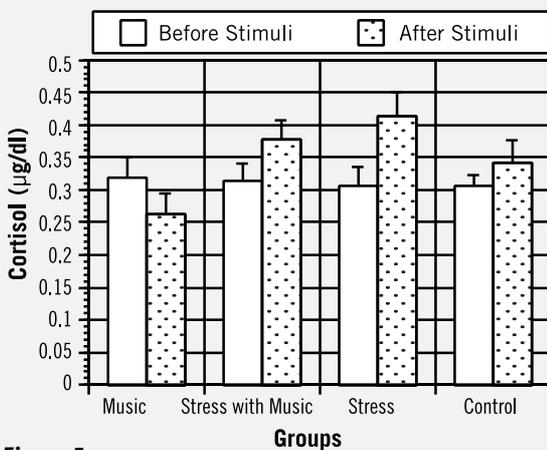


Figure 5.

Figure 4. C levels of 44 male subjects sampled at 30 min interval. ANOVA revealed that the effect of C changes and the effect of conditions was not significant ($p=ns$), but the effect of condition-by-C change interactions was significant ($F(3, 40)=5.334, p=.0035$). C decreased in the music condition and increased in the stress condition.

Figure 5. C levels of 44 female subjects sampled at 30 min interval. ANOVA revealed that the effect of C changes was significant ($F(1, 40)=8.916, p=.0048$), the effect of condition was not significant ($p=ns$), and the effect of condition-by-C change interactions was significant ($F(3, 40)=7.387, p=.0005$).

Table I. Pretest and posttest mood disturbance scores for the four conditions.

Group	Pretest		Posttest		P value
	M(point)	SD	M(point)	SD	
Control	39.600	12.198	42.953	9.276	.2596
Stress	41.000	10.212	52.364	9.130	.0001
Music	39.864	9.130	34.409	8.721	.0200
Stress with Music	40.727	7.611	59.318	9.968	<.0001

of C changes was significant ($F(1, 40)=8.916, p=.0048$), the effect of condition was not significant ($p=ns$), and the effect of condition-by-C change interaction was significant ($F(3, 40)=7.387, p=.0005$) (Figure 5).

In pooled data for males and females, ANOVA-R revealed no difference in the effect of sex ($p=ns$) or in the interaction of sex and condition ($p=ns$). There were no significant effects from major or from menstrual cycle in the females ($p=ns$).

Total POMS scores obtained before and after stimulation in each of the four conditions were analyzed by paired *t*-test. In the results, there were no significant changes in the control condition ($p=ns$), but the POMS value increased significantly after stimulation in the stress condition and in the stress with music condition ($t=-4.618, p=.0001$; $t=-7.452, p<.0001$). In the music condition, the POMS value decreased significantly after stimulation ($t=2.518, p=.0200$). There was a strong correlation between listening to music, stress, and mood. Positive mood changes occurred after listening to music, while stress alone and stress with music induced negative changes (Table I).

To compare the effects of condition, sex, and music experience (major) on total mood disturbance between, before, and after stimulation, ANOVA-R was carried out. In the results, there was no significant effect of sex; however, conditions ($F(3, 80)=14.900, p<.0001$) and interaction of conditions with POMS changes revealed a significant effect ($F(3, 80)=15.431, p<.0001$). Post-hoc test (Fisher's PLSD) revealed a significant difference between the control and stress condition ($p=.0039$), between the control and stress with music condition ($p<.0001$), between the music and the stress condition ($p<.0001$), and between the music and the stress with music condition ($p<.0001$). No significant difference involving major or menstrual cycle resulted.

To examine relationships among changes over time in POMS, T, and C, Spearman correlation coefficients were calculated.

In males, a weak correlation was found between POMS and C changes ($\gamma=.280, p=.0654$), between POMS and T changes ($\gamma=.327, p=.0296$), and between C and T changes ($\gamma=.324, p=.0312$). In females, there was a weak correlation between POMS changes and C changes ($\gamma=.359, p=.0161$), but there was almost no correlation between POMS changes and T changes, and between C and T changes ($p=ns$).

Subjects were asked about their music preference. 96 percent of subjects in the music condition and the stress with music condition responded that they "liked" listening to music, and all subjects in the stress condi-

tion and the music and stress condition responded that they "disliked" the visual stimulation.

Discussion

The results of the present study indicate that there are wide sex-related differences in stimulated T secretion. In the male subjects, T responses changed depending on condition; T decreased with the music condition and increased in the presence of stress and stress with music. On the contrary, in the female subjects, T increased with all stimuli. In music condition, T especially decreased among male subjects and increased among female subjects.

Meanwhile, C responses to each stimulus were the same between the two sexes. It increased with the stress condition, increased gradually with the stress with music condition, and decreased with the music condition.

Regarding both hormones examined, no significant differences existed in the liking (preference) of music or between music and non-music majors in either sex, or in menstrual cycle in the female subjects. Positive mood changes occurred after listening to music, whereas stress induced negative changes. There were no differences in mood changes between the two sexes or between the majors, although higher POMS scores were obtained from the stress with music condition. Because the stress stimulus (movie film) used in the present study resulted in increased C levels and increased POMS scores, it is considered to meet the requirements of stress stimulation. In addition, because the music used as a stimulus was accepted with the answer "I like" by almost all subjects, and also because their POMS scores and C values decreased after music listening, the music stimulation is considered as preferable and stress-modifying. In the stress and music condition, stimulated with a stressful movie and music at the same time, the POMS score and C value increased after intervention. This finding is incompatible with the general thought that music modifies stress. It can be conjectured, however, that a sense of incompatibility or a lack of harmony between the "preferable" music and "undesirable" movie used as stimuli in the present study might increase the subject's discomfort, which in turn might serve as a strong stress stimulus.

A correlation analysis based on differential changes in C, T, and POMS revealed a relatively strong correlation between T and C and a relatively weak correlation between T or C and POMS in the male subjects. In the female subjects, there was almost no correlation

between C and T or between T and POMS, although a weak correlation was found between C and POMS. The female subjects, like the male subjects, showed a positive correlation between C and T in the control, stress, and stress with music condition. In contrast, the female subjects in the music condition showed a reverse (negative) correlation between C and T. Hence, sex-related differences and stimulation-related differences were observed in the relationship between T and C.

Generally, C increases in the presence of physical or mental stress. Music has been reported to decrease C, and our data agrees with previous studies [35, 56]. Moreover, music effectively suppressed stress responses in both sexes, since even in the presence of both music and visual stress, the increases of C were suppressed in both sexes compared with visual stress only. As described above, researches done in related field on the relationship between T responses and psychological stress in each sex showed that T decreased under psychosomatic and psychic stress in the male subjects and increased in the female subjects. Our findings that T rose under visual stress in both sexes do not coincide with the previously reported results showing that watching a stressful movie (dental surgery) decreased T in males and increased in females [18, 57]. However, our results agree with reported T changes in both sexes with fatigue and competition [58, 59]. Because the video film used as a stimulus in the present study mainly concerned fighting scenes, it is likely that changes similar to those during fight might be induced in the subjects.

The finding that 30 min of music suppressed T in the male subjects and increased T in the female subjects does agree with a previously reported result [49]. However, this raises a further question. Why are T responses induced by music listening?

The mechanism of hormonal change induction by music listening remains unclear. However, sensory information concerning all senses except olfaction is transmitted to the higher brain region via the thalamus. Located between the cerebral cortex and the hypothalamus, the thalamus plays a major role in the onset of emotion. The hypothalamus provides superior control over the pituitary function mediated by the nervous and endocrine systems, thus regulating endocrine functions in response to external and internal stimuli to the sensory organs and the cerebrum. Music and other auditory information is relayed to the lateral and medial geniculate bodies (both belonging to the metathalamus nucleus group) and reaches the cerebral auditory area, and auditory information is considered to induce the secretion of various hormones via the pathways through the thalamus, hypothalamus and cerebral limbic system.

Stress responses in the brain are based on the nervous and nerve endocrinological functions mainly by the hypothalamus-pituitary-adrenal (HPA) axis, and T and C changes can be considered within this framework. It is known that HPA activity under normal or stressful conditions involves sex-related differences, resulting in differences in adrenocorticotrophic hormone (ACTH) secretion between the two sexes. Both C and

T are controlled by ACTH, a hormone produced in the pituitary gland and the sex-related differences in T secretion under stressful conditions are considered to reflect the sex-related differences in the functions of T-producing organs. In males, T is produced in the testis in response to stimulation mainly by gonadotropin-releasing hormone (GnRH) and luteinizing hormone (LH). It is also produced in the adrenals upon stimulation by ACTH but the amount produced is small. On the contrary, ACTH suppresses GnRH production, resulting in suppressed T production in males. The involvement of corticotropin releasing hormone (CRH) is also likely. Secreted by the hypothalamus upon stress responses, CRH promotes ACTH secretion. CRH is also known to accentuate sensitivity to auditory stimulation, to suppress the secretion of growth hormone and gonadotropin, and to suppress sexual behavior. On the other hand, in females, T is produced in the adrenals and ovaries; however, the majority of its secretion is derived from the adrenals upon ACTH stimulation. In summary, stress activates the HPA axis to induce the production of CRH and ACTH. In males, stress promotes the production of CRH and ACTH, which in turn suppresses T secretion. In females, T secretion from the adrenals is accentuated under the influence of ACTH, resulting in sex-related differences in T responses.

It is considered that in the present experiments, stress-like responses were induced by musical stimulation. However, this finding poses another question. Generally, music represents a comfortable stimulus, rather than a stress. Despite this fact, hormonal changes occurred as in the presence of stress. On the other hand, noise is known to be associated with similar responses [60] but it represents an uncomfortable stimulus. Why does music listening yield the same results as physically and mentally painful stress responses? Becerra *et al.* [61] proposed that pain (heat stimulation) activated not only the classic pain circuitry but also the reward circuitry. If this is true, constant hormonal changes may occur whether the stimulus is a pain or pleasure. Such painful stimuli turn into pleasure in the runner's high phenomenon as well.

T is known to affect a broad spectrum of human behavior, including aggressiveness, fight, dominance, emotion and immunity. Although there still remains some ambiguity in human studies, there is overwhelming evidence that T mediates aggressive behavior, and that low T levels correlate with low aggressiveness in both sexes [62–65]. If this is true, some control mechanisms reducing aggressiveness is adaptive for the human. Suppression of T by music in males is attributable to its possible function as a regulator of aggressiveness. However, the relationship between aggressiveness and T is reportedly constant between males and females; increases in T by music mean increases in aggressiveness and this is opposite to the generally recognized effect of music. In this regard, further investigation is necessary.

Desire for dominance has also been shown to have a positive correlation with T values in males [66]; T level reductions by music mean increases in the sense

of solidarity and harmony. Much less research has been conducted on the links between testosterone and dominance and status among women than in men. A study has reported that desire for dominance has a negative correlation with T values in females in contrast to males [67]. If this is true, T level increases by music mean decreases in desire for dominance and increases in the sense of solidarity and harmony.

Regarding the relationship between T and mood, no conclusion can be reached. A report is available showing that T values have a negative correlation with depression and anxiety and a positive correlation with joyfulness in males, and that males with higher T values have higher depression scores [15]. It should be noted, however, that a study reported a positive correlation between T values and mood (anger, tension) in 32 male or female subjects [68]. In the present study, T values showed a correlation with total mood disturbance in males listening to music, suggesting that the improvement in mood may be attributable to reductions in T values in males. In females, however, there was no correlation between total mood disturbance and T values. Further investigation is necessary on the relationship between T and mood under music listening conditions.

Moreover it is not conclusive, but known that T suppresses the immune system, whereas estrogen protects immune function [69–71]. T reductions in males during music listening have positive effects on immunity in males. In females, however, T elevations have negative effects, although their immunity is not adversely affected actually because estrogen, a promoter of immunoglobulin production, is dominant in this gender.

Much remains unknown about the relationship between music and the human endocrine system. The present study revealed sex-related differences in T responses to listening to music favored by the subject. Further investigation is necessary to evaluate the relationships between music and other substances, the effect of degree of preference and hormonal changes not only during music listening but also during music plays and creation. Such studies are expected to bring new points of view and deepen our understanding of the biological nature of musical behavior.

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