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*Review Article*

# Lifestyle, Stress and Cortisol Response: Review II
## — Lifestyle —

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### Abstract

**To prevent lifestyle related diseases, it is important to modify lifestyle behavior. The control of mental stress level and prevention of mental stress-related diseases have become one of the most important problems in Japan. To check mental stress level objectively during the early stage of stress-related diseases and determine appropriate coping methods, it is necessary to design a useful index for mental stress. Cortisol is a steroid hormone secreted by the adrenal cortex. This is an essential hormone to human survival, and plays a key role in adaptation to stress. In another review, we concluded that cortisol appears to be an adequate index for mental stress.**

**However, lifestyle factors such as alcohol drinking, smoking, lack of exercise etc., are strongly associated with mental stress. Thus, in this review, we focus on the relationship between cortisol and lifestyle.**

**The present findings suggested that lifestyle factors; smoking, alcohol drinking, exercise, sleep and nutrition are strongly associated with cortisol levels, and it may be impossible to determine whether alterations in cortisol levels are due to mental stress.**

**It was suggested that those lifestyle effects on not only mental stress itself but also cortisol levels should be considered, when assessing mental stress by cortisol levels.**

**Key words:** lifestyle, cortisol, each health practice, preventive medicine, mental stress

## Introduction

There have been many epidemiological and experimental studies which discussed the relationship between cancer, obesity and diabetes etc. and individual health practices; smoking, alcohol drinking, food and stress. To prevent disease, it is important to modify lifestyle behavior. The prevention of mental stress-related diseases has become an important concern recently. To allow mental stress level to be determined objectively during the early stage of stress-related diseases and design appropriate coping methods, it is necessary to have a useful mental stress index. Following the pioneering work by Hans Selye[1)], the pituitary-adrenal system has been viewed as central to human adaptation to changes in the internal and external environment. In another review, it was suggested that cortisol appears to be an adequate index for mental stress (review I). Cortisol is a major steroid hormone secreted by the adrenal cortex and is a possible candidate as an index for mental stress[2–4)].

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Daily stress is known as an important factor in various kinds of disease such as cancer, cardiovascular diseases, obesity, diabetes etc., although the mechanisms of the effects in these conditions are not clear. Poor lifestyle factors such as alcohol drinking, smoking, lack of exercise etc., are strongly associated with mental stress[5–6)].

Thus, in this review, we focus on the relationship between cortisol and lifestyle.

## 1. Smoking

Nicotine has been shown to be a potent stimulator for the release of several hypothalamic-pituitary-adrenal (HPA) hormones[8)]. The HPA appears to be a prime endocrine target of nicotine action[8)].

Injection of nicotine results in elevated serum levels of cortisol[9,10)]. However, some studies have indicated nicotine had no or only a slight effect on cortisol levels[11,12)].

The basal level of cortisol was reported to be higher in smokers than in non-smokers[13–15)]. The elevation of cortisol level has been reported to be dependent on the number of cigarettes smoked per day[16–18)], although contradictory findings have also been reported[19)]. Cigarette smoking is considered to induce frequent release of hormones that in turn lead to an altered responsiveness of the endocrine axes[8)]. Cigarette smoking is a potent and acute stim-

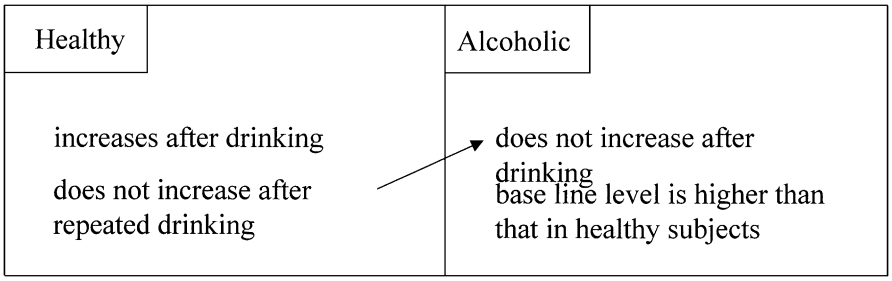


**Fig. 1 The relationship between alcohol drinking and cortisol level.**

ulus for various hormonal axes in healthy smokers.

After a smoking cessation trial, although the basal level was not different, the level of cortisol decreased in smokers who succeeded in cessation[20,21]. This was consistent with the observation that increasing the level of nicotine was associated with the rise in the cortisol level. However, gender-related differences have also been reported[22–24], and these differences are thought to be due to sex hormones.

We was suggested that acute and chronic smoking generally increased cortisol levels, because smokers showed higher cortisol levels than non-smokers, especially after a high dose of smoking, which showed higher levels of cortisol, and quitting smokers showed decreased cortisol levels compared with smoking duration. The conflicting findings were thought to show the individual differences of adrenal responses, physical stress response, metabolism and other various hormone effects[19].

## 2. Alcohol (Fig. 1)

Ethanol may stimulate the basal function of the HPA axis involved in centrally mediated stress responses[25,26]. Many studies have shown that acute and short-term ethanol injection in normal subjects causes increases in cortisol level[27–33]. Some of these studies indicated that the elevation of the plasma cortisol level showed parallel changes with the blood ethanol curve[28–30]. A number of studies have demonstrated activation of the HPA axis associated with an increase in plasma cortisol levels after administration of high doses of ethanol, but not low doses of ethanol[31–33].

It has also been shown that repeated alcohol injection did not produce any elevation in cortisol level in normal subjects[34–38]. Other studies indicated that increases in cortisol levels induced by acute injection were observed only in non-drinkers who had symptoms of alcohol intolerance, but not in heavy drinkers or in alcoholic patients[39]. It is also well established that long-term alcohol consumption induces endocrine abnormalities, especially in the HPA axis[26].

Three independent studies of investigators examined cortisol levels in Asian subjects who either did or did not show alcohol-induced flushing[40–42]. Approximately 50% of certain Asian groups are $ALDH^2$ deficient[40–42]. $ALDH^2$ deficiency is very uncommon among other non-Mongolian ethnic groups[40–42]. These studies demonstrated higher levels of cortisol following an alcohol challenge in Asians who experience alcohol-induced flushing.

In healthy people, the cortisol levels increase after drinking and do not increase after repeated drinking, but in alcoholics, the cortisol levels do not increase after drinking and basal levels of cortisol are higher than those in healthy people. Thus, it was suggested that adequate alcohol-drinking people showed normal adrenal responses but heavy and chronic alcohol drinking abnormal effect on adrenal responses. In Asians, alcohol-induced flushing should be considered.

## 3. Nutritional balance — obesity and malnutrition — (Fig. 2)

There is little evidence to support an important relationship between the mental state or behavior of obese patients and their hormone levels. Nutrition plays a role in determining the endocrine abnormalities often found in obesity or malnutrition.

Obese subjects show increased cortisol production and metabolism[43–47]. The Cortisol excretion rate is positively correlated with body mass index[45]. In contrast, some studies indicated nor-

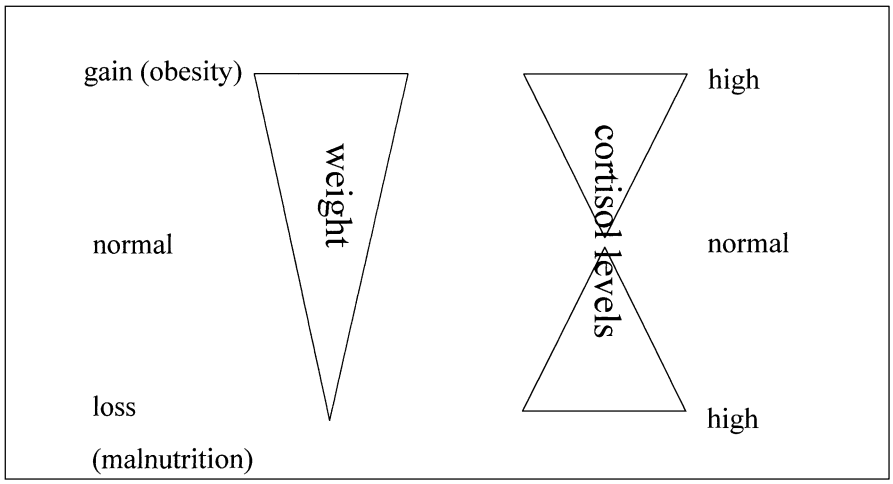


**Fig. 2 The relationship between cortisol levels and obesity or malnutrition.**

mal plasma cortisol levels and circadian rhythm in obese subjects and concluded there was no correlation between plasma levels of cortisol and weight of obese subjects[48,49].

Nutritionally deprived subjects generally show increased plasma levels of cortisol[50–55]. Energy deficiency causes marked changes in the metabolic and endocrine state of the human body[50–55]. Obese patients, after periods of starvation or reduced caloric intake or weight loss, have been reported to show either increased or normal plasma levels of cortisol[43,44,56]. Malnutrition is associated with decreased responsiveness of the HPA axis, and these abnormalities are restored after nutritional rehabilitation[57–61]. These tendencies have been observed in both children and elderly subjects. Children with protein-calorie malnutrition have been shown to have raised of plasma cortisol levels[53,55].

It is suggested that both extreme weight gain and loss are related to the rise of cortisol levels[43–47]. These might be caused by marked changes in the metabolic and endocrine abnormalities of human body[50–55], because following body weight becoming normal, cortisol levels also return to normal[43,44,56].

## 4. Sleep

The circadian rhythms of cortisol are known to be slightly affected by acute modifications in the sleep-wake cycle such as sleep deprivation or and abrupt disruption of the sleep-wake schedule. Some studies have shown that the cortisol concentration is influenced by sleep itself[62–65]. However, it is difficult to distinguish between the effects of sleep and the natural circadian rhythm.

Night workers are known to adapt only partially to the nocturnal schedule[66]. The cortisol levels were low during the night shift, suggesting that night shift itself represents a high stress level. Circadian rhythms of cortisol were fundamentally maintained even during the night shift. However, the cortisol concentration in the morning, at the end of the night shift, was significantly lower than that during the day shift[67].

Alterations in cortisol levels could only be demonstrated in the evening following a night of sleep deprivation[68–71]. Sleep deprivation results in an elevation in the cortisol level the following evening[68–70]. The effects of total sleep deprivation on HPA function correspond to the absence of these immediate responses to sleep-wake transitions. During the month of Muslim fasting (Ramadan), many people alter their sleeping habits and stay awake most of the night. Thus, Ramadan is a period of sleep deprivation. Four of 10 subjects showed alterations in the cortisol rhythm during the last 2 weeks of Ramadan[71].

Irregular sleep, such as sleep deprivation and shift work, effects on the circadian cortisol rhythms. However, the findings were not inconsistent, because it is difficult to distinguish between the effects of sleep and the natural circadian rhythm, and there are few studies that examined the relationship between the quality of sleep, sleeping hours and cortisol levels.

## 5. Physical exercise (Table 1)

Many factors are involved in individual variability in cortisol responses related to physical exercise. In this review, we categorized three factors, “Intensity of exercise and duration of exercise, Environmental effects and Type of sports” (Training, competition and performance level).

Intensity of exercise

The cortisol response to exercise is determined by threshold intensity[72–81]. The serum level of cortisol is known to increase when a certain workload is exceeded[72,73]. Cortisol increases during exercise if the intensity of the exercise exceeds 60% of maximal $VO_2^{max}$ after more than 1 h[74]. However, conflicting observations were reported in some studies[75–80]. No increase in blood cortisol level after exercise at workloads above 70% of $VO_2^{max}$[81]. In short, cortisol levels are not increase correspondent to the workloads. These findings suggested that only intensity of exercise might not affect the measurement of cortisol responses.

*Types of sport*

Competition

In tennis players, cortisol levels in blood were shown to be elevated 15 min before the match[82]. In elite rowers, high anticipatory levels of cortisol were detected during an international competition[83].

**Table 1 The relationship between exercise and cortisol reaction**

| Factors | | Cortisol reaction |
|---|---|---|
| Intensity of exercise | VO2max over 70% | No change |
| | over 60% | ↑ |
| Types of sports | Competition | |
| | Tennis players | No change (increase 15 min before a match) |
| | Rowers | ↑ |
| | Training | |
| | Weightlifting | ↑ |
| | Runners | ↑ |
| | Swimmers | ↑ |
| | Performance level | |
| | Weightlifting | ↑ (positively related to performance level) |
| | Rowers | ↑ (positively related to performance level) |
| Environmental effect hot temperature | | ↑ (compared to cold temperature) |
| | High altitude | ↑ |

↑: Means that cortisol level increases after exercise (including competition and training)

Training effects

Previously, cortisol was identified as a hormonal marker of training stress[84]. Recent studies have indicated endocrine changes in endurance sportsman during a training year[85–88]. Lukaszewska et al. reported increases in cortisol in adolescent males after a weightlifting session[85]. Barron et al. observed that athletes who were overtrained had impaired cortisol and elevated basal cortisol levels compared to a control group of runners[88]. Stray-Gundersen et al. also reported a significant elevation in cortisol levels in recreational runners subjected to two weeks of normal training superimposed with four hard interval sessions per week[89]. However, Flynn et al. concluded that the response of cortisol to training stress was unclear and, therefore, they doubted its usefulness as a marker of training stress[90].

Performance level

Kraemer et al. demonstrated that cortisol showed no differences due to training experience or strength classifications in junior weightlifters[91]. A longitudinal study of rowers demonstrated a parallel increase in rowing performance and blood cortisol level[92]. Elevated cortisol level in rowers reflects the increased functional capacity of the corresponding endocrine systems[92]. Resting cortisol concentrations declined more slowly during the morning in amenorrheic athletes than they do in regularly menstruating athletes and sedentary women[93].

Environmental effects

It was demonstrated that changes in secretory activity in response to exercise were not only closely correlated with muscular work intensity, but were also influenced by thermal stress[94,95].

It was shown that thermal stress caused increases in cortisol levels[96–99]. During swimming, the concentrations of cortisol are higher when the environment is hot[98,99]. Dulac et al. found that cortisol concentrations in blood were significantly increased during long-distance swimming in cold water[98].

Serum cortisol level increases in response to exercise at moderated altitude[99–101]. Guilland et al. observed increased urinary excretion of cortisol during mountaineering between 4,800 and 7,100 m[102]. Strassman et al. reported that a 46-km mountain race (between 1,900 and 3,300 m) tripled serum concentrations of cortisol[103].

Cortisol increased to levels above the normal range, particularly during indoor running with an internal focus of attention[104]. Vigorous exercise can have a beneficial effect on mood, but the environment and setting in which it occurs and the attentional focus appear to exert mediating effects.

Competition and training include both mental and physical stress effects[82–83]. In general, physical activity was associated with increase of cortisol levels[82–83]. However, there were many confounding factors such as the intensity of exercise, type of sports (competition, training effects and performance levels) and environmental effects[72–104]. When the physical activity, mental stress and cortisol levels are examined, it is necessary to consider how hard, how long, how many times subjects exercise.

Other considerable effects

The elevation of cortisol levels has also been suggested to be caused by the stress of blood collection[4]. Lower cortisol stress responses have been consistently shown in females compared to males[105]. Personality and other traits may influence how stressful situations are appraised and may, thus, have predictive value for understanding individual differences in emotional and physiological responses to apparently identical situations[106–108]. More insight into individual differences in cortisol reactivity is needed.

## Conclusion

Lifestyle factors such as alcohol drinking, smoking, lack of exercise etc., are strongly associated with cortisol levels, which are widely accepted to be related to various types of mental stress[8–108].

Cortisol responses to mental stress have been found to differ between individuals, but the sources of these differences are far from clear. Under these conditions, it may be impossible to determine whether the observed alterations in cortisol are due to mental stress. Based on the findings of a number of previous studies related to lifestyle and cortisol, it is suggested that lifestyle factors are strongly associated with change in cortisol levels. Lifestyle effects on not only mental stress itself but also cortisol levels should be considered, when assessing mental stress using cortisol levels. It is necessary to improve the more comprehensive mental stress index survey including lifestyle and other strong effects such as gender, age and character.

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