



Hormonal changes when falling in love

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Summary To fall in love is the first step in pair formation in humans and is a complex process which only recently has become the object of neuroscientific investigation. The little information available in this field prompted us to measure the levels of some pituitary, adrenal and gonadal hormones in a group of 24 subjects of both sexes who had recently (within the previous six months) fallen in love, and to compare them with those of 24 subjects who were single or were part of a long-lasting relationship. The following hormones were evaluated by means of standard techniques: FSH, LH, estradiol, progesterone, dehydroepiandrosterone sulphate (DHEAS), cortisol, testosterone and androstenedione.

The results showed that estradiol, progesterone, DHEAS and androstenedione levels did not differ between the groups and were within the normal ranges. Cortisol levels were significantly higher amongst those subjects who had recently fallen in love, as compared with those who had not. FSH and testosterone levels were lower in men in love, while women of the same group presented higher testosterone levels. All hormonal differences were eliminated when the subjects were re-tested from 12 to 24 months later. The increased cortisol and low FSH levels are suggestive of the "stressful" and arousing conditions associated with the initiation of a social contact. The changes of testosterone concentrations, which varied in opposite directions in the two sexes, may reflect changes in behavioural and/or temperamental traits which have yet to be clarified. In conclusion, the findings of the present study would indicate that to fall in love provokes transient hormonal changes some of which seem to be specific to each sex.

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1. Introduction

The formation of pair bonding is relevant in several animal species, and particularly in mammals since, in some cases, it ensures not only that a new couple is formed which can thus generate

offsprings, but also that a safe and stable environment is set up wherein the newborn can receive sufficient care to enable them to mature and become capable of surviving alone (Bowlby, 1969; Kleiman, 1977; Carter et al., 1997a, 1997b).

The process of pair bonding in humans begins with the subjective experience of falling in love, which sometimes leads to the establishment of long-lasting relationships: for this reason, its function exceeds that of reproduction alone and, given

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its relevance to the survival of the species, it would not be surprising if it were regulated by precise and longstanding neural mechanisms (Uvnäs-Moberg, 1997, 1998; Carter, 1998). Indirect evidence of the biological process involved in falling in love is provided by cross-cultural studies which suggest that it is present in virtually all societies and is, perhaps, genetically-determined (Jankowiak and Fischer, 1992). Furthermore, common features of this process can be identified in studies from all over the world and include: perception of an altered mental state, intrusive thoughts and images of the other, sets of behavioural patterns aimed at eliciting a reciprocal response and a definite course and predictable outcome (Leckman and Mayes, 1999).

One of the first biological hypotheses with regard to falling in love associates this state to increased levels of phenylethylamine, on the basis of the similarities between the chemical structure of this neurotransmitter and that of amphetamines which provoke mood changes resembling those typical of the initial stage of a romance; however, no empirical data have been gathered to support this theory (Liebowitz, 1983). The strong suggestion is that different mechanisms may be involved (Panksepp, 1982; Jankowiak, 1986; Hazan and Shaver, 1987; Fisher, 1992; Porges, 1998; Insel and Young, 1997) and it has been recently demonstrated that the intrusive thoughts of the early, romantic phase of a falling in love are underlain by a decreased functionality of the serotonin transporter (Marazziti et al., 1999).

The complexity of the process would seem, therefore, to be understood better when we consider falling in love as a basic emotion, such as anxiety or fear, due to the activation of the amygdala and related circuits and neurotransmitters (Bartels and Zeki, 2000; LeDoux, 2000). Consistent with this hypothesis is the observation that stress and threatening situations may facilitate the onset of new social bonds and intimate ties (Bowlby, 1973; Reite, 1985; Kraemer, 1992; Panksepp et al., 1994). The review of animal data is beyond the scope of this paper, however it should perhaps be noted also that stress and corticosterone have been demonstrated to promote pair bonding formation in different species (DeVries et al., 1995, 1996; Hennessy, 1997; Levine et al., 1997; Mendoza and Mason, 1997). Furthermore, these elements induce the synthesis and release of neuropeptides, such as oxytocin, which are involved in the subsequent processes, including sexual and maternal behaviours and, more in general, positive social contacts, which reduce anxiety (McCarthy et al., 1992; Numan, 1994; Carter, 1998). The literature relevant to humans in this

regard is meagre, albeit in agreement with animal findings and suggests that the activation of the hypothalamic-pituitary-adrenal (HPA) axis due to stressful experiences or, more in general, to arousal, may trigger the development of different kinds of social attachment, possibly also that which begins with falling in love (Milgram, 1986; Chiodera et al., 1991; Simpson and Rhole, 1994).

Given the paucity of data in this field and the unexplored questions regarding the possible role of gonadal hormones, our study aimed at evaluating the levels of some pituitary, adrenal and gonadal hormones in a homogenous group of subjects of both sexes who were in the early, romantic phase of a loving relationship, and to compare them with those of subjects who were single or were already in a long-lasting relationship.

2. Subjects and methods

2.1. Subjects

Twenty-four subjects (12 male and 12 female, mean age \pm SD: 27 ± 4 years) who declared that they had recently fallen in love, were recruited from amongst residents (17) and medical students (7), by means of advertisement. They were selected according to the criteria already applied in a previous study (Marazziti et al., 1999), in particular: the relationship was required to have begun within the previous 6 months (mean \pm SD: 3 ± 1 months) and at least four hours a day spent in thinking about the partner (mean \pm SD: 9 ± 3 hours), as recorded by a specifically designed questionnaire.

Twenty-four subjects (12 female and 12 male, mean age \pm SD: 29 ± 3), belonging to the same environment and with similar educational levels, with either a long-lasting (mean \pm SD: 67 ± 28) months or no relationship, served as the control group.

No subject had a family or personal history of any major psychiatric disorder or even sub-threshold symptoms, or had ever taken psychotropic drugs, except for three who occasionally took benzodiazepines because of difficulties in sleeping at night, as assessed by a detailed psychiatric interview conducted by one of the authors (DM). In addition, all subjects were undergone the following rating scales: the Hamilton Rating Scale for Depression (Hamilton, 1960), the Hamilton Rating Scale for Anxiety (Hamilton, 1959) and the Yale-Brown Obsessive-Compulsive Rating Scale (Goodman et al., 1986), with the results that all total scores fell within the normal range.

All subjects, except for four singles (three women and one man), were indulging in a normal and regular sexual activity, as assessed by self-report questionnaires and, during the psychiatric interview, no differences were noted between the romantic lovers and the control subjects.

The women had regular menstrual cycles and were not taking contraceptive pills. Their blood samples were drawn in the early follicular phase (between the third and the fifth day of the menses); the men had no history of genital disease or hypogonadism. All subjects were free of physical illness, were neither heavy cigarette smokers nor belonged to high-risk HIV individuals and all underwent a general and detailed check-up, carried out by one of the authors (DC).

All gave their informed written consent to their inclusion in the study.

2.2. Hormonal measurements

Venous blood (10 ml) was collected between 8 and 9 a.m. from fasting subjects and centrifuged at low-speed centrifugation ($200 \times g$, for 20 min, at 22°C) to obtain serum which was stored at -20°C until the assays, which were performed within a few days.

The following hormones were evaluated by means of standard techniques in duplicate for each point, by biologists who were blind to each subject's conditions: FSH, LH, estradiol, progesterone (chemiluminiscent immuno-assay, CMIA, Architect, Abbott, Abbott Park, USA), dehydroepiandrosterone sulphate (DHEAS) (Spectria, Orion Diagnostic, Essoo, Finland), cortisol (CMIA, DPC, Immulite, Los Angeles, USA), testosterone and androstenedione (RIA, Testo-CTK, Diasorin Biomedica, Saluggia, Italy).

2.3. Statistics

The differences in hormone levels between subjects of the two sexes who recently had or had not fallen in love were measured by means of the Student t-test (unpaired, two-tailed). The possible effects of the length of the relationship or of the time devoted to thinking about the partner on the hormonal levels were assessed according to Pearson's analysis. All analyses were carried out using the SPSS version 4.0, by means of personal computer programs (StatView V) (Nie et al., 1998).

3. Results

Table 1 shows that cortisol levels (ng/ml) were significantly higher in the subjects who had recently fallen in love, as compared with control subjects (239 ± 39 vs 168 ± 31 , $p < 0.001$), with no difference between women and men.

The levels of LH, estradiol, progesterone, DHEAS and androstenedione did not differ between the groups and were within normal ranges according to the sex and the follicular phase of the women.

On the other hand, testosterone levels (ng/ml) in men who had recently fallen in love were significantly lower than in singles or individuals with a long-lasting relationship (4.1 ± 1.0 vs 6.8 ± 2.1 , $p > 0.003$); the results in women were the opposite, that is, higher levels in the women from the first group, as compared with those from the second (1.2 ± 0.4 vs 0.6 ± 0.2 , $p < 0.001$).

FSH levels were significantly lower in men who had fallen in love than in those from the control group ($p < 0.0001$).

When the cortisol, testosterone and FSH levels were re-tested in 16 out of the total of 24 sub-

Table 1 Hormonal levels in subjects in the early stage of falling in love and in control subjects

	Subjects in love		Control subjects	
	M	F	M	F
FSH	$3.2 \pm 1.1^{\wedge}$	8.1 ± 4.2	9.3 ± 3.8	9.1 ± 3.1
LH	6.9 ± 2.3	12.3 ± 3.4	7.1 ± 2.8	10 ± 4.3
Estradiol	< 50	170 ± 23	< 50	145 ± 32
Progesterone	< 0.2	0.57 ± 0.3	< 0.2	0.55 ± 0.3
Testosterone	$4.1 \pm 1.0^*$	$1.2 \pm 0.4^{**}$	6.8 ± 2.1	0.6 ± 0.2
DHEAS	2736 ± 1122	2232 ± 986	2450 ± 1000	2315 ± 980
Cortisol	$224 \pm 21^{\circ}$	$243 \pm 41^{\circ\circ}$	165 ± 21	172 ± 44
Androstenedione	2.0 ± 1.0	2.1 ± 0.7	2.1 ± 0.7	1.9 ± 0.7

M, male; F, female.

$^{\wedge}$ Significant: $p < 0.0001$; * Significant: $p < 0.003$; ** Significant: $p < 0.001$; $^{\circ}$ Significant: $p < 0.001$; $^{\circ\circ}$ Significant: $p < 0.0001$.

jects in-love, from 12–28 months later, no differences from control subject levels were detected. Hormonal measurements were also repeated in 15 out of the total of 24 control subjects after the same time interval, but no significant differences from those of the first assessment were noted (data not shown).

The length of the relationship and the time spent in thinking about the partner did not affect hormonal levels.

Singles or subjects with a long-lasting relationship did not differ in any of the parameters evaluated.

4. Discussion

The main bias of this study is probably represented by the criteria used for selecting the subjects who had fallen in love since, despite our best efforts, no definite indication was available. Since the altered mental state associated with falling in love seems to have a precise time course, with an average duration of between 18 months and 3 years (Tennov, 1979; Marazziti et al., 1999), we chose the length of the relationship as one criterion which, furthermore, can easily be recorded. The other main criterion adopted was the time spent in thinking about the partner which, according to various authors, represents a core feature of this phase (Tesser and Paulhus, 1976; Tennov, 1979; Shea and Adams, 1984). One might perhaps infer that the subjects who are in love suffer from a moderate form of OCD, or have an obsessive-compulsive personality, a positive family history of OCD or even obsessive-compulsive subthreshold symptoms: however, we excluded all these possibilities by means the psychiatric interview and specific questionnaires. It might also be judged questionable that our hormonal evaluation was performed on a single sample; however this could represent a bias for LH measurement only, for which a pulsatile pattern is well-recognized.

However, in spite of this limitation, our study led to some intriguing and innovative findings, in particular that healthy subjects of both sexes who had recently fallen in love did show some hormonal changes.

The first finding was that the cortisol levels were higher in subjects in love, as compared with those from the control group. This condition of "hypercortisolemia" is probably a non-specific indicator of some changes which occur during the early phase of a relationship, reflecting the stressful conditions or arousal associated with the initiation of a social contact which helps to overcome neophobia. Such conditions appear to be fundamental, as a moderate level of stress has

been demonstrated to promote attachment and social contacts in both animals and humans (DeVries et al., 1995, 1996; Hennessy, 1997; Levine et al., 1997; Mendoza and Mason, 1997). In addition, different data indicate an association between HPA activation following stressful experiences and the development of social attachment which, in turn, promotes physiological states which reduce anxiety and related negative sensations (Hinde, 1974; Milgram, 1986; Simpson and Rhole, 1994; Legros, 2001). We observed no difference in cortisol levels between women and men, but this is perhaps not surprising, given indications that they represent rather an unspecific reaction to different triggers.

On the other hand, while LH, estradiol, progesterone, DHEAS and androstenedione levels did not differ between men and women, the testosterone concentrations showed some sex-related peculiarities: in both men and women who were at the early stage of a relationship, they were lower and higher, respectively, than those in men and women from the control group. Although none reached pathological levels, all subjects presented this finding, as if falling in love tended temporarily to eliminate some differences between the sexes, or to soften some male features in men and, in parallel, to increase them in women. It is tempting to link the changes in testosterone levels to changes in behaviours, sexual attitudes or, perhaps, aggressive traits which move in different directions in the two sexes (Zitzmann and Nieschlag, 2001), however, apart from some anecdotal evidence, we have no data substantiating this which would justify further research. Similarly, we have no explanation for the decreased level of FSH in male subjects who were in love, apart from the suggestions that it may represent another marker of hypothalamic involvement in the process of falling in love.

It is noteworthy that when we measured the cortisol, testosterone and FSH levels for a second time, 12–18 months later, in those 16 (out of the total of 24) subjects who had maintained the same relationship but were no longer in the same mental state to which they had referred during the first assessment and now reported feeling calmer and no longer "obsessed" with the partner, the hormone levels were no different from those of the control group. This finding would suggest that the hormonal changes which we observed are reversible, state-dependent and probably related to some physical and/or psychological features typically associated with falling in love.

In conclusion, our study would suggest that falling in love represents a "physiological" and tran-

sient condition which is characterized (or underlaid) by peculiar hormonal patterns, one of which, involving testosterone, seems to show a sex-related specificity.

Studies are now in progress to establish whether the noted hormonal changes may be related to the modifications of specific behaviours, such as aggression or sexual or attachment attitudes.

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