Universiteit
Leiden
The Netherlands

Vitamin D: ultraviolet light and well-being of older people

Veleva, B.I.

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Chapter 4

Effect of Ultraviolet Light on Mood, Depressive Disorders and Well-being

Bistra I Veleva [1 2], Rutger L van Bezooijen [1 3], Victor G M Chel [1],
Mattijs E Numans [1], Monique A A Caljouw [1]

[1]*Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, The Netherlands.*
[2]*Woonzorgcentra Haaglanden, Den Haag, The Netherlands.*
[3]*Florence Health and Care, Rijswijk, The Netherlands.*

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ABSTRACT

Background

Human and animal studies have shown that exposure to ultraviolet light can incite a chain of endocrine, immunologic and neurohumoral reactions that might affect mood. This review focuses on the evidence from clinical trials and observational studies on the effect of ultraviolet light on mood, depressive disorders, and wellbeing.

Methods

A search was made in PubMed, Embase, Web of Science, Cochrane, Psychinfo, CINAHL, Academic Search Premier and Science Direct, and the references of key papers, for clinical trials and observational studies describing the effect of ultraviolet light applied to skin or eyes on mood, depressive disorders, and wellbeing.

Results

Of the seven studies eligible for this review, the effect of ultraviolet light on mood, depressive symptoms and seasonal affective disorders was positive in six of them

Conclusions

Of the seven studies, six demonstrated benefit of exposure to ultraviolet radiation and improvement in mood which supports a positive effect of ultraviolet light on mood. Because of the small number of the studies and their heterogeneity more research is warranted to confirm and document this correlation.

INTRODUCTION

Depressive disorders are an important clinical problem as they can decrease the quality of life of the patient and caregiver [1]. Depressive disorders are associated with functional impairment, cognitive changes, and increased morbidity and mortality [2-4]; unfortunately, their prevention and treatment remain a challenge. Despite the relative effectiveness of antidepressant medication and psychological treatment, major depression in older persons over longer follow-up periods shows a chronic remitting course or, in some patients, has a chronic character [4]. This implies the need for alternative methods to treat depressive disorders in the elderly.

Sunlight has long been used to treat different medical conditions. For example, Niels Ryberg Finsen demonstrated that ultraviolet (UV) light can have a curative effect in lupus vulgaris (a skin variant of tuberculosis); in 1903, he was awarded the Noble Prize for Medicine and Physiology. Nowadays, UV light is an important treatment option for several skin diseases including psoriasis, atopic dermatitis, morphea, scleroderma, vitiligo, and mycosis fungoides[5].

A mood-enhancing effect of UV light has also been reported [6-9]. This effect might be accomplished via two target organs working as receptors for UV light: i.e. skin and eyes.

A possible mood-modulating effect of UV light via the skin is through the vitamin D pathway. The major source of vitamin D for humans is exposure of the skin to sunlight (UVB 280-315nm) resulting in the conversion of 7-dehydrocholesterol to pre-vitamin D3. The recent discovery that the human brain also possesses vitamin D receptors [10,11] indicates that mood and depressive disorders might be influenced by vitamin D deficiency directly, by acting on brain cells.

Other pathways that may be triggered by UV light to modulate mood and act through skin exposure involve three local systems: i) the skin analog of the hypothalamic-pituitary-adrenal (HPA) axis [12], ii) the serotoninergic/melatoninergic system [13], and iii) the immune system [14,15]. These pathways are assumed to interplay with systemic mechanisms of body homeostasis [14].

Using eyes as a target, bright light therapy is applied for the treatment of seasonal affective disorders (SAD); it is thought that bright light can help suppress melatonin production in the pineal gland, thereby attenuating many of the symptoms associated with SAD [16]. However, it remains unclear whether UV light has an additional value in the therapeutic light spectrum, or whether it exercises only a deleterious effect on the eyes.

Bearing in mind the theoretical points mentioned above, this review explores and summarizes the evidence obtained from clinical trials and observational studies on the effect of UV light applied to the skin or as a component of light therapy applied to the eyes on mood, depressive disorders, and wellbeing.

METHODS

Protocol and registration

This systematic review was designed according to the PRISMA method [17,18]. The protocol is registered and published in the PROSPERO database (PROSPERO 2017: CRD42017059971).

Eligibility criteria

A PICO (population, intervention, control, outcome)-based search strategy was conducted on 22 March 2017. Eligible for this review were studies in the general population in which: i) exposure to UV light or sunlight was used as an intervention, and ii) the effect on mood, depressive disorders, and wellbeing was measured as an outcome. Included were clinical trials and observational studies on sunlight, in which exposure to sunlight occurred outdoors and the number of exposure hours was recorded.

Search strategy

With the assistance of an experienced librarian the following bibliographic databases were searched: PubMed, Embase, Web of Science, Cochrane, Psychinfo, CINAHL, Academic Search Premier and Science Direct. Also, the references of key papers and of the included studies were explored. The search strategy included terms related to UV light, mood, affective disorders, and wellbeing (for the PubMed search strategy see Appendix A). Although no restriction was made regarding the date of publication, articles had to be in English, Dutch, German or Russian.

Study selection

Of the identified studies, the titles and abstracts were screened by the first author (BV) and categorized on exclusion criteria. The categories were reviewed by the second author (RvB) by randomly assessing the titles and abstracts in the different categories; differences were discussed until consensus was reached. References from the included studies and from key articles were also assessed. The full-text articles derived from this process were independently assessed by the first and second author; any differences were discussed until consensus was reached.

Data Extraction

Information extracted from the selected studies included: year of publication, study design, study population (characteristics of chronic disease, if any), setting (community, or hospitalized), intervention and control conditions, outcome measures on mood and results, and information for assessment of risk of bias. The first and second author extracted data from the studies independently from each other; any discrepancies were resolved by discussion.

Risk of bias

Risk of bias of the individual studies was evaluated on outcome level by the first and second author independently, using Cochrane Collaboration's tool for assessing risk of bias [19]. Risk of bias assessment comprised evaluation of sequence generation, allocation concealment, blinding of participants and outcome assessors, incomplete outcome data, selective outcome reporting, and other bias. Disagreements were resolved through discussion and consensus, or by consulting the last author (MC).

Data synthesis and analysis

All outcomes on mood, depressive disorders and wellbeing reported in the studies were extracted. For each study, characteristics including study size, population, intervention, control group, main outcome measures, and follow-up period were described. Synthesis and analysis were done in a narrative manner and structured according to the site of action of UV light: skin or eyes.

RESULTS

Study selection

After removing duplicates from the 702 articles yielded by the search, 677 records remained (Figure 1). After screening on title (no UV light, sunshine, mood, mood disorders or wellbeing) and language, 532 publications were excluded and 145 publications remained. After evaluating these 145 papers on abstract, another 126 were excluded for the following reasons: 9 were ideas, editorials or theoretical reviews, 17 concerned vitamin D and depression but no intervention with UV light, 96 examined the effect of light therapy on depression but UV light was not used as a therapeutic fraction of light spectrum, and 4 explored the relation between vitamin D and sunlight but not in connection with mood, mood disorders, or wellbeing.

Following assessment of the remaining 19 full-text articles for eligibility, 12 studies were excluded: 3 RCT's that had no control group without UV light, 4 examined the effect of sunlight on mood on subjects while staying indoors (no direct contact of ultraviolet light to skin or eyes), 4 did not measure mood variables but preference for UV light as the only psychological parameter, and 1 was a systematic review.

Finally, 7 studies were regarded eligible for this systematic review. All examined the effect of UV light or sunlight on mood, wellbeing or depressive disorders, applied directly to skin or eyes as an intervention in a group of healthy people, or patients diagnosed with a chronic disease. In 6 of these 7 studies, a control group was used for comparison, and one of the studies was observational.

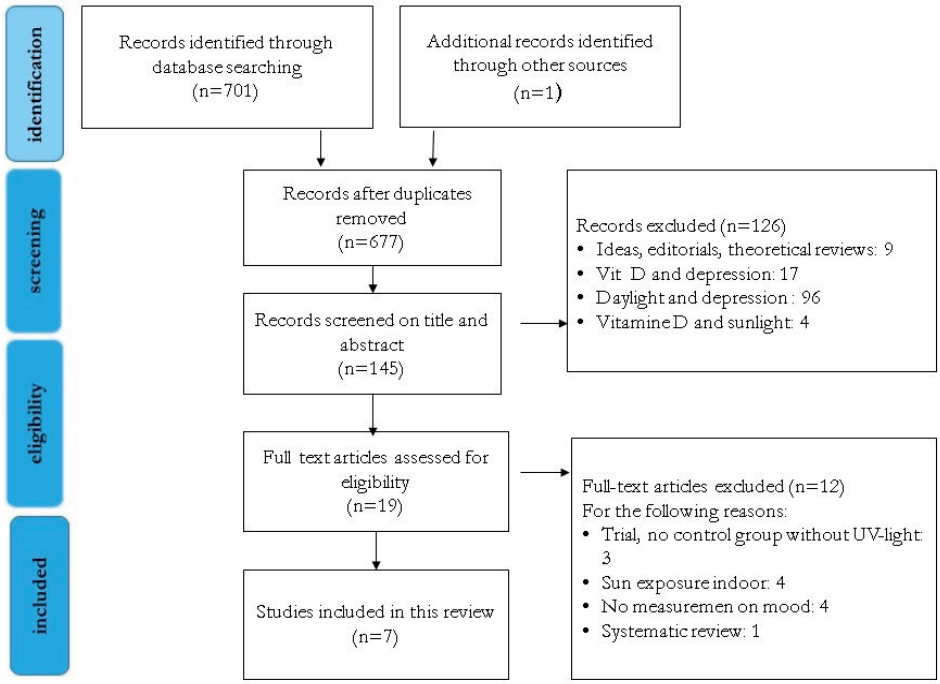

Figure 1 Prisma-based flowchart of the literature search, selection, and review process

Study characteristics

Seven studies were assessed in this review [5,16,20-24], i.e. 6 clinical trials of which 2 randomized controlled trials (RCTs), 2 cross-over studies, 1 prospective clinical trial, 1 study with a randomized parallel design, and 1 observational study. The characteristics of these studies are presented in Table 1.

Participants

Participants in the selected studies were healthy volunteers [22], and patients with fibromyalgia syndrome [20], dermatological conditions [5], multiple sclerosis (MS) [21], and SAD [16,23,24]. The numbers of participants per study ranged from 13 [23] to 198 [21].

Methods of selected studies

All studies included a control group, except the observational study [21]. The control groups consisted of: i) patients belonging to the same cohort but not receiving the intervention [20,22,24], ii) two control groups of which one of the same cohort having the intervention applied on a smaller surface of the body and one composed of healthy volunteers (receiving or not receiving the intervention) [5], or iii) the study had a cross-over design [16,24].

Table 1 Data extraction sheet and study characteristics

Study	Intervention	Site of action	Outcome measures	Results
Mood				
Gambichler et al., 2002 RCT not blinded; N=53; Volunteers	Group 1: UVA whole body Group 2: No UVA	Skin (2x/week, 10-15 min)	1. BBS 2. FKB-20 T1 (baseline), T2 after first exposure, T3 end of study	1. UVA exposed volunteers were more balanced (p=0.01), less nervous (p=0.03), more strengthened (p=0.009) at T3 in comparison to T1 2 UVA exposed volunteers showed more robustness and strength (p=0.011) and more satisfaction with their own appearance (p=0.04) at T3 in comparison to T1
Taylor et al., 2009 RCT, partly blinded, a pilot, N=19, Patients with fibromyalgia syndrome	Group 1: UV (4% UVB, 96% UVA) Group 2: No UV	Skin, A. Acclimation phase: 6 sessions non UV bed, followed by UV bed B. RCT phase: 18 sessions, 3 x week, 10 min each	1. PANAS (positive affect) 2. PANAS (negative affect)	A. Acclimation phase: 1. Increased positive affect (p=0.003) as measured by: -tanning bed preference (p <0.0001) -well-being (p = 0.001) -relaxation (p <0.0001) 2. Decreased negative affect (p <0.018) as represented by: -tension (p = 0.02) -distress (p = 0.03) -nervousness (p = 0.026) Changes in being active, enthusiastic, alert, attentive or sad were not significant before and after UV -exposure B. RCT phase: No data
Depression scores and depression				
Edstrom et al.,2010, Prospective clinical trial, N=77 Patients with dermatological conditions and healthy volunteers	Patients -Group 1: WBI (Whole body irradiation) UVA/UVAB/PUVA) -Group 2: PUVA on hands/feet Volunteers Group 3: WBI (UVB/UVA) Group 4: Placebo	Skin, 2 a 3/ week	MADRS	- No significant difference between groups in the baseline MADRS. -Highly significant improvement in MADRS score in patients with WBI (p < 0.001), tendency towards improvement in the healthy group with WBI (p = 0.08) -Both patients and volunteers divided in groups: UVA, UVB, UVAB: Significant improvement in UVB and UVAB group in MADRS (p<0.001 and p<0.01, respectively)
Knippenberg et al., 2014, Prospective longitudinal cohort study, N=198, Duration of 2.5 years Patients with MS	No	Skin and possibly eyes	-Depressive symptoms and anxiety measured with HADS (0-21) - Sun exposure, quantified in time spent in the sun - Serum 25(OH) D	- Personal reported sun exposure was inversely associated with depression scores ((β-0.26 (95% CI -0.40, -0.12), p≤0.001 When both 25 (OH) D and sun exposure were included in de model, the magnitude of sun exposure remained stable (β: -0.26 (95% CI-0.40, -0.11)) p=0.001, 25 (OH) D remained non-significant P=0.667

Table 1 Data extraction sheet and study characteristics (continued)

Study	Intervention	Site of action	Outcome measures	Results
Lam et al., 1991 Triple crossover study, pilot, N=13, Patients with recurrent major depression, Seasonal pattern	A. 1 week: 2500 lux cool-white fluorescent light with UVA By non-response/ relapse: B.1 week: 2500 lux cool-white fluorescent light By non-response/ relapse: C. 500 lux cool-white fluorescent light	Eyes (three 1-week intervals, 2 hours per day)	1.SIGH-SAD 2. BDI	A.. Dim light (500 Lux) had a small, not statistically significant effect on HAM-D, BDI and ATYP scores B. UV-light condition produced a statistically significant effect on HAM-D, BDI, ATYP compared with other two conditions, resp. p<0.003, p<0.02, p<0.008 C.. The UV-blocked condition produced significant improvement only in atypical symptoms of depression p<0.02
Pudikov et al., 2012 Crossover clinical trial, N=24, Patients with seasonal depression	24 patients were examined in different years. Group 1: Phototherapy in the optical range Group 2: Same as group 1 but enriched in UVA	Eyes (25 days, 2 sessions of 60 min. with interval between sessions increasing each day)	1. HDRS-SAD, Based on the opinion of the attending physician 2. BDI, based on the assessment of patient.	1. Tendency to unidirectional changes in the results on HDRS-SAD and BDI scales during both therapy's (p<0.05) 2. The patient's state is most markedly improved in the first week of phototherapy irrespective of the method used. 3. In week 3 and 4 of therapy the maximum efficiency was observed in the group with combined optical and UV radiation which was statistically significant only with respect to HDRS-SAD (p =0.03 and p=0.01 respectively)
Lam et al, 1992, Randomized parallel design N=35, patients with recurrent major depression, seasonal pattern	Light therapy with full spectrum lenses Group 1: UV-blocked condition Group 2: UVA condition	Eye (2 weeks, 2 hours per day)	1. SIGH-SAD 2. BDI	1. The analysis of SIGH-SAD scores did not find significant effect of condition (p<0.70), nor condition-by-time (p<0.70). 2. Analysis of BDI didn't find significant effects of condition (p<0.25), nor condition –by-time (p<0.20). 3. Both analysis have found only a significant effect of time (p<0.0001)

BBS = Basler Befindlichkeits- Scala, FKB -20 = Fragebogen zum Körperbild, PANAS = Positive and Negative Affect Scale, MADRS = Montgomery-Asberg Depression Rating Scale, HADS = Hospital Anxiety and Depression Scale, HDRS-SAD = Hamilton Depression Rating Scale-Seasonal Affective Disorders Version, BDI = Beck Depression Inventory, SIGH-SAD = Structured Interview Guide for the HAM-D, SAD version

All studies used a repeated measure design for evaluation of the effect of the intervention.

Interventions

The studies can be categorized into two groups according to the target site of the intervention: in one group the targeted organ was the skin [5,20-22], whereas in the other the intervention was applied to the eyes (with the retina as target) [16,23,24].

The intervention used in the selected studies was UV light [5,20,22], optical light combined with UV light ([16,23,24], or outdoor exposure to sunlight [21]. In five of the studies, UV light was explicitly defined as UVA light (315-400 nm) [16,20,22-24] and in one study different groups were specifically receiving UVA, UVB (280-315 nm) or UVA+UVB light [5].

In the 4 studies in which skin was the target, UV light was applied either to the whole body [5,22], to smaller body areas [5], or was not specified [20]. The duration of UV light exposure to the skin ranged from 3-6 weeks (2-3 times a week for 10-15 min). In the study with sun exposure, the duration of sun exposure was calculated in hours spent in the sun during the weekends and holidays between summer 2002 and summer 2005 [21].

Phototherapy in studies targeting the retina was applied for 1, 2 or 3 weeks. Duration of the interventions per day was either 2 sessions of 60 min in the morning and afternoon [16], or 1 session of 2 h in the morning [23,24].

Outcome measures

This systematic review focuses on the outcome measures mood, depressive disorders, and wellbeing.

Mood

Mood was assessed in two studies. In the study with patients with fibromyalgia, mood was evaluated with the PANAS (Positive and Negative Affect Scale) [20]. In the study with healthy volunteers, emotional state and physical awareness were assessed with the BBS (Basler Befindlichkeits- Scala) and the FKB-20 (Fragebogen zum Körperbild), respectively [22].

Depression

Depression was assessed in five studies. Depression was evaluated with the CPRS-S-A (Comprehensive Psychopathological Self-Rating Scale for Affective Syndromes) which had been transformed to correspond to the MADRS (Montgomery-Asberg Depression Rating Scale) in patients with dermatological conditions and healthy volunteers as a control group [5].

Depression symptoms and anxiety were measured with the HADS (Hospital Anxiety and Depression Scale) in patients with MS [21]. HDRS-SAD (Hamilton Depression Rating Scale-Seasonal Affective Disorders Version) and the BDI (Beck Depression Inventory) were used in

all studies comparing phototherapy in the optical range, with phototherapy in the optical range enriched in UV light in patients with SAD [16,23,24].

Well-being

Although wellbeing was frequently mentioned in two studies [5,20], none of these studies used a measurement scale specified for wellbeing.

Risk of bias

The results of the risk of bias evaluation are summarized in Table 2; in some cases a narrative explanation is given for further clarification.

Table 2 Risk of bias criteria in individual studies

Study, first author	Sequence generation	Allocation concealment	Blinding participants and outcome assessors	Incomplete outcome data	Selective outcomes reporting	Other or bias
Gambichler et al., 2002	LR	?	HR	LR	HR	Competing Interests
Taylor et al., 2009	?	LR	LR	LR	HR	LR
Edstrom et al., 2010	?	?	HR	LR	?	LR
Knippenberg et al., 2014	Observational study	Observational study	LR	LR	LR	High risk, related to study design
Lam et al.,1991	LR	LR	LR	LR	LR	Order effect Small number participants
Lam et al., 1992	?	LR	LR	LR	LR	Compliance to treatment not guaranteed
Pudikov et al., 2012	?	?	HR	LR	LR	LR

LR – Low risk, HR – High risk,? - Not clearly reported, unclear risk of bias

All studies gave little or no information on the sequence generation and allocation concealment. Significant bias was found in all studies as a consequence of study design. None of the studies met all the criteria of a double-blinded randomized control study with a good statistical power. Both studies by Lam et al. had a low risk bias according to the Cochrane Collaboration's tool of bias [23,24]. However, the first study had little power because of the small number of participants and a possible order effect that can confound multiple cross-over designs [23]; the second study raises questions about the compliance of patients who performed the intervention at home [24]. Although Knippenberg et al. performed a study with long duration and many participants, the observational character of the study was a limiting factor [21]. Gambichler et al. mentioned that not blinding their participants may have influenced their results [22]. Edstrom et al. performed a study creating groups with different UV light exposure, different spectrum

of the UV light, and a two-control group design, but with limited possibility to blind the participants and assessors because of the different interventions [5]. Taylor et al., apart from not blinding the assessors, provided no information on mood changes in the second (randomized control) phase of their study [20]. These authors focused on improvement of mood after each UV session in the acclimation phase when each participant underwent 6 tanning sessions at which they were exposed to two beds: a non-UV control bed and a UV treatment bed, which might simply be a consequence of an order effect, determined by the preference for a UV bed.

Results of individual studies

Results of the individual studies are presented in Table 1.

Mood

Both studies using UV light targeted to skin and examining the psychological parameters showed a significant improvement in mood. Gambichler et al. concluded that UVA exposed volunteers were more balanced, less nervous, more strengthened and robust, and more satisfied with their own appearance after 3 weekly sessions of whole body UVA exposure [22].

Taylor et al. showed increased positive affect and decreased negative affect after UV stimuli in the acclimation phase of their study (6 sessions non UV, followed by a UV bed) as measured by tanning preference, tanning expectations, increased wellbeing, relaxation, and decreased tension, stress and nervousness [20]. The adjusted mean for the PANAS negative affect (10 low-50 high) after UV exposure in patients with fibromyalgia was 13.5 (SE 0.84) compared to 13.8 (SE 1.00) after the control session (p=0.019). The adjusted mean for the PANAS positive affect (10 low-50 high) after UV exposure was 29.3 (SE 1.84) compared to 28.3 (SE 1.75) after the control sessions (p=0.030).

Depression scores

Four out of the 5 studies that investigated the effect of UV light reported a positive effect of UV radiation on depression scores in the examined populations. Both studies that applied UV exposure to the skin reported positive effects (Edstrom et al. 2010; Knippenberg et al. 2014), two studies that applied UV exposure to the eye reported positive effects (Lam et al. 1991, Pudikov et al. 2012), and one study that applied UV exposure to the eye reported no positive effect on depression (Lam et al. 1992).

Edstrom et al. demonstrated a significant improvement in MADRS in both dermatological patients and volunteers after 6 weeks (2-3 sessions weekly) UVB exposure of the whole body and significant improvement of MADRS in dermatologic patients who received whole body irradiation with UVA or combined UVA/UVB irradiation with the same duration [5]. The median of the MADRS score in the group of the dermatological patients with whole body

UV-irradiation was 8 (IQR 4-13) before the treatment, and 4 (IQR 2-7) after the treatment. The median of the MADRS score in the group of the volunteers receiving whole body UV irradiation was 5 (IQR 4-10) before the treatment, and 4 (IQR 0-5) after the treatment. However, because a MADRS score below 20 is considered non-pathological, these data do not describe the effect of UV light on depression, but only on depressive scores. The authors stated that wellbeing improved as the MADRS score decreased.

Knippenberg et al. showed that higher levels of reported sun exposure were associated with lower depression scores in an observational cohort study of 198 MS patients with a follow-up of 2.5 years [21]. Of the 198 observed patients, 38 patients had the diagnosis depression. The association between sun exposure and HADS depression score in patients with MS was β = -0.44 (95% CI 0.89, 0.01, p=0.056) with 1.5 h/day sun exposure and β = -0.79 (95% CI -1.34, -0.25, p=0.005) with 3.5 h/day sun exposure.

Three studies examined the effect of phototherapy enriched in UVA light exposed to the eye on depressive episodes of patients with SAD. Two of these three studies concluded that maximum efficiency of phototherapy on depression was observed in the groups receiving combined optical and UVA light [16,23]. In the first study, the UVA light condition was the only treatment in which the traditional measures of depression and the HAM-D scores ($p < 0.003$) and BDI scores ($p < 0.02$) were significantly reduced ([23] after 1-week treatment periods, one hour per day with different light spectrum and intensity. In the second study in week 3 and 4 of the treatment, the maximum efficiency of 4-week treatment two hours per day was observed in the group with combined optical and UVA radiation which was significant only with respect to HDRS-SAD ($p = 0.03$ and $p=0.01$, respectively), but not to the BDI score [16]. The third study found that addition of UV light to the optical spectrum in the phototherapy was not beneficial for alleviation symptoms of SAD during 2-week light treatment [24].

Area exposed to UV light

One of the studies proposed that UV light exposure of the whole body (rather than one part of the body) may be superior in influencing mood in a positive manner [5]; however, no other studies examined this aspect.

Benefits of UV spectrum

In most of the studies, the fraction of UV light used was UVA light. In the study of Edstrom, however, it was shown that UVB light was superior to UVA light in improving depressive symptoms [5].

DISCUSSION

Main findings

After an extensive search in multiple bibliographic databases, 145 papers were screened on title and abstract and 19 publications were assessed for eligibility. Of these publications, 7 met the inclusion criteria and are discussed in this systematic review.

The selected studies with skin as the target organ for UV light [5,20-22] were relatively heterogeneous. There was diversity in the population examined, in the psychological instruments used to assess mood and depressive disorders, and in the spectrum of the UV light that was applied. Although mood and depressive symptoms were analyzed in all these studies, they were not always the primary outcome. Other outcomes of UV light treatment were also investigated, e.g. effect on pain, fatigue, and dermatological conditions. However, the effect of UV light on mood and depressive symptoms was consistently corrected for these other conditions.

The overall effect of UV light intervention on mood was positive in the two studies that examined this effect. [20,22]. However, the bias present in them made the results inconclusive. None of the two studies using depression scales as a measurement for depressive symptoms conducted a separate analysis in a subgroup of depressed participants [5,21]. The study population was a combination of people with depression, depressive symptoms and people without depression. Anyway both of them showed improvement of depressive scores after treatment with UV-light or sunlight. In the study observing the effect of sun exposure on depressive symptoms in patients with MS two mechanisms are discussed as possibly involved in the improvement of the depressive scores : the immunologic and endocrine mechanisms of UV light and the effect of bright light [21].

The trials targeting the retina with optical light enriched with the UV fraction were performed with a homogenous population of patients with SAD [16,23,24]. The UV light used in the studies was UVA light fraction added to the optical range. The studies had depression as their main outcome and the psychological instruments used to measure depression were comparable. Despite the homogenous populations and the comparable instruments used, the effects of UV light on SAD were variable. Duration and intensity of the light treatment in those studies was different and all of them had some degree of risk of bias.

Strengths and limitations

For this review an extensive search was made in major electronic databases and the references in key and selected articles were checked. All of the selected studies, apart from one that was observational [21], used a control group, assessed mood and depressive disorders with more than one psychological instrument, and performed repeated measurements. The one observational

study was of longer duration and had good statistical power. The effects in the observational study and the controlled studies (although relatively heterogeneous in character) concurred with each other.

Most RCTs had problems with allocation concealment and blinding. In the trials with UV light intervention affecting the skin, tanning can be a confounder and, if not blinded, can disturb the results. In one of the studies, the participants were blinded for the tanning and the lamps whereas the assessors were not [20].

In one of the studies, the number of participants was too low to have any statistical power [23]. In two of the studies, a per-protocol analysis was performed that could have influenced evaluation of the effect of the intervention [5,22]; on the other hand, this may have provided a better picture of the effect of the treatment.

Finally, because of the small number of studies which met the inclusion criteria and the small amount of dispersion in the sample size, publication bias cannot be excluded.

Comparison with other studies

Research on the beneficial effects of UV light on mood and depression is still in its infancy [25]. The effect of UV light on skin as a target organ in improving mood and depressive disorders has not yet been examined by systematically reviewing the existing literature. To our knowledge this is the first review to focus on this effect. An interesting prospective controlled study of Meffert et al. [26], not included in our review because a double intervention was used (UV and infra-red (IR) light), reports on the effect of 10 low-dose UV and infrared (IR) irradiations of elderly people with inflammatory degenerative muscle and bone disease. Under controlled conditions, suberytemal amounts of UV and IR resulted in some favorable and continual effects like increase in serum 25(OH) D level, decrease of pain, and improvement of wellbeing and training state. It may be useful to reproduce this study in separate groups with UV light and IR light only, and a control group.

To study the effect of UV light applied to the retina in the treatment of SAD, Lee et al. [27] performed a meta-analysis on spectral properties of phototherapy in these disorders. They found no difference in the treatment efficacy between full spectrum light with UV component, full spectrum light without UV component, and green-yellow light in SAD. However, due to insufficient information on the search strategy and eligible articles, no meaningful conclusions can be drawn.

A possible mood-modulating effect of UV light via the skin is through the vitamin D pathway. Many observational studies found a significant negative correlation between 25(OH)D levels

and depression in people ≥60 years [28-33]. In a recent meta-analysis, however, no evidence was found for a reductive effect of vitamin D supplementation on depression in adults [34].

Similarly, a recent prospective observational study of Knippenberg et al, included in our review, reported that sun exposure, rather than 25(OH)D levels, was associated with fewer symptoms of depression and fatigue in patients with multiple sclerosis [21]. The relation between vitamin D, UVB and mood is still not well understood and possibly not all beneficial effects of UV radiation exposure occur through UVB induced vitamin D synthesis [25], as we already discussed in the introduction.

CONCLUSIONS AND IMPLICATIONS

Of the 7 included studies, 6 showed a positive effect of UV light on mood, depressive scores or SAD which supports a positive correlation between ultraviolet light exposure and mood improvement. However, the small number of studies, their heterogeneity and the small number of participants in some studies, the existing bias, and the suboptimal study designs make it difficult to draw general conclusions about the effect of UV light on mood and depressive disorders.

Dating from ancient times, researchers have suggested that sunshine, apart from its deleterious effects, also has curative effects. Because of the seasonal and meteorological changes, we cannot use sunshine in an unlimited way. This has triggered research to determine the components in sunshine that may have a beneficial effect on health, as well as their artificial reproduction. The administration of bright white visible light is considered to be the treatment of choice for patients with SAD [35,36]. We have concentrated on the UV component of sunshine and its effect on mood and depressive disorders. The results of the reviewed studies, the available knowledge on UV light mechanisms, and the neural, endocrine and immune regulation of mood provide sufficient information to warrant further research in this area. First of all, appropriate UV exposure schedules need to be established to predict and control DNA damage [37]. Second, a good design of future studies (double-blind, RCTs with sufficient power) are required. In addition, studies in the general population, as well as in cohorts of people with depressive disorders, are needed. Important aspects in this are a good definition and differentiation of the light spectrum, determination of the therapeutic range of the intervention, and the duration of the effect which can be ensured by repeated measurements.

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