

## Efficacy of Anti-inflammatory Agents to Improve Symptoms in Patients With Schizophrenia: An Update

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**Background:** The inflammatory hypothesis of schizophrenia is not new, but recently it has regained interest because more data suggest a role of the immune system in the pathogenesis of schizophrenia. If increased inflammation of the brain contributes to the symptoms of schizophrenia, reduction of the inflammatory status could improve the clinical picture. Lately, several trials have been conducted investigating the potential of anti-inflammatory agents to improve symptoms of schizophrenia. This study provides an update regarding the efficacy of anti-inflammatory agents on schizophrenic symptoms in clinical studies performed so far. **Methods:** An electronic search was performed using PubMed, Embase, the National Institutes of Health web site <http://www.clinicaltrials.gov>, Cochrane Schizophrenia Group entries in PsiTri, and the Cochrane Database of Systematic Reviews. Only randomized, double-blind, placebo-controlled studies that investigated clinical outcome were included. **Results:** Our search yielded 26 double-blind randomized controlled trials that provided information on the efficacy on symptom severity of the following components: aspirin, celecoxib, davunetide, fatty acids such as eicosapentaenoic acids and docosahexaenoic acids, estrogens, minocycline, and *N*-acetylcysteine (NAC). Of these components, aspirin (mean weighted effect size [ES]: 0.3,  $n = 270$ , 95% CI: 0.06–0.537,  $P = 0$ ), estrogens (ES: 0.51,  $n = 262$ , 95% CI: 0.043–0.972,  $P = 69\%$ ), and NAC (ES: 0.45,  $n = 140$ , 95% CI: 0.112–0.779) showed significant effects. Celecoxib, minocycline, davunetide, and fatty acids showed no significant effect. **Conclusion:** The results of aspirin addition to antipsychotic treatment seem promising, as does the addition of NAC and estrogens. These 3 agents are all very broadly active substances, and it has to be investigated if the beneficial effects on symptom severity are indeed mediated by their anti-inflammatory aspects.

**Key words:** add-on antipsychotic therapy/aspirin/*N*-acetylcysteine/estrogens

### Introduction

Forty years ago, Torrey and Peterson<sup>1</sup> proposed that inflammatory processes play a key role in the pathophysiology of schizophrenia. Since then, different pieces of evidence have been gathered to suggest that there is an increased proinflammatory status in the brain of patients with schizophrenia. This proinflammatory status is thought to result from the interaction between genetic vulnerability and environmental factors such as infections, trauma, nutrition, and stress.<sup>2</sup> Associated with this increased proinflammatory status is a decrease in the neurotrophic function of microglia and other supportive central nervous system (CNS) cells and enhanced production of neurotoxic proinflammatory factors such as tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ), free radicals, complement factors, and kynurenic acid.<sup>3,4</sup> This shift leads to decreased proliferation of the neurons, resulting in reduced connectivity and eventually a loss of brain tissue.<sup>5</sup> Increased proinflammatory status of the brain also interacts with glutamatergic and dopaminergic neurotransmission, which can induce or aggravate positive, negative, and cognitive symptoms of schizophrenia.<sup>6,7</sup>

Over the years, evidence has accumulated to support this theory. In recent years, some important data have been added. For example, strongest genetic association with schizophrenia is found in the major histocompatibility complex genes including loci that influence the immune response.<sup>8</sup> Peripheral blood markers, such as C-reactive protein, have been linked to cognitive impairment in patients with schizophrenia.<sup>9–11</sup> Positron emission tomography studies using ligands that bind to the peripheral benzodiazepine receptor, which is expressed also on astrocytes<sup>12,13</sup>

but mainly on activated microglia cells, showed increased binding capacity in the brains of patients with early-stage schizophrenia<sup>14,15</sup> but not in chronic disease stages.<sup>16</sup> Finally, the prevalence of autoimmune disorders, such as multiple sclerosis, type I diabetes, and systemic lupus erythematosus, is increased in patients with schizophrenia and in their first-degree relatives.<sup>17-19</sup> The attractiveness of the immune hypothesis lies in the possibility that the shift towards a more proinflammatory status in the brain can potentially be corrected with anti-inflammatory agents. Although it is not yet proven that such agents can induce microglia or other cells to resume their neurotrophic function,<sup>5</sup> many anti-inflammatory agents can reduce the production of toxic proinflammatory factors. In a recent meta-analysis on augmentation with nonsteroid anti-inflammatory drugs (NSAIDs), we showed modest but significant symptom improvement in patients with schizophrenia.<sup>20</sup> However, a wide variety of components have anti-inflammatory properties and could potentially reinstate the balance between proinflammation and anti-inflammation in patients with schizophrenia. Table 1 lists the main types of medication with anti-inflammatory actions, although this summary is far from complete as many herbal and nutritional components also have anti-inflammatory actions.

In addition, most psychiatric medications such as antipsychotics, lithium, valproate acid, and selective serotonin reuptake inhibitors also possess some anti-inflammatory aspects.<sup>26-29</sup> As can be viewed in table 1, most anti-inflammatory components are broadly active, with their anti-inflammatory capacity being just one of their many actions. Some of these components have been given to patients with schizophrenia in an attempt to reinstate the balance between pro- and anti-inflammation in the brain. So far, results of these studies were inconsistent. This quantitative

review provides an update of the efficacy of different types of anti-inflammatory agents, given in augmentation to standard treatment, to improve symptom severity in patients with schizophrenia. We include both agents that are considered primary anti-inflammatory agents such as NSAIDs and corticosteroids, but also components that possess additional anti-inflammatory actions, such as *N*-acetyl cysteine (NAC), estrogens, melatonin, davunetide, and fatty acids. For obvious reasons, we will not include psychiatric medication with anti-inflammatory actions.

## Methods

### Literature Search

This meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement.<sup>30</sup> An electronic search was performed using PubMed, Embase, the National Institutes of Health web site <http://www.clinicaltrials.gov>, Cochrane Schizophrenia Group entries in PsiTri, and the Cochrane Database of Systematic Reviews.

No year or language restrictions were applied. The following basic search terms were used: schizophrenia AND the specific pharmacological components: NSAIDs (aspirin, celecoxib, ibuprofen, diclofenac, naproxen), davunetide, EPA and DHA fatty acids, estrogen (and raloxifen and tamoxifen), specific antibiotics (eg, minocycline), NAC and corticosteroids (prednisone, prednisolone, hydrocortisone, methylprednisolone, dexamethasone, cortisone, triamcinolone, betamethasone), transplantation adjuncts (tacrolimus, cyclosporine, everolimus, sirolimus, mycophenolate mofetil), cytostatics (bexarotene, bone marrow irradiation/transplantation, methotrexate, cyclophosphamide), and melatonin.

**Table 1.** Main Types of Medication With Anti-inflammatory Actions

Anti-inflammatory Components	Crosses BBB	Actions in the Brain
Antipsychotics	++	Dopamine receptor blockade (D2), ↑BDNF <sup>18</sup>
Aspirin	-/+	PG↓, TNF-α↓ <sup>19</sup>
Celecoxib	++	COX-2↓, PG↓ <sup>18</sup>
Cytostatics	-/+	Diverse, eg, for MTX: TNF-α↓ <sup>20</sup>
Davunetide	++	TNF-α↓ <sup>18</sup>
Estrogens	++	TNF-α↓, NO↓ <sup>21</sup>
Fatty acids	++	Zinc↑, TNF-α↓, COX-2↓, IL-1↓ <sup>18</sup>
Leptin	++	IL-4↓, IL-10↑, IFN-γ↓ <sup>22</sup>
Macrolides/tetracyclines	++	IL-1β↓, NO↓ <sup>23,94</sup>
Melatonin	++	NO↓, IL-1β↓, TNF-α↓, NF-κβ↓ <sup>18</sup>
Minocycline	++	Microglia inhibition, TNF-α↓ <sup>24</sup>
Monoclonal antibodies	-/+	Inhibition of one specific component
NAC	++	IL-1β↓, TNF-α↓ <sup>25,95</sup>
Corticosteroids	-/+	Inhibition of many steps in innate and specific immune response
Transplantation adjuncts	-/+	IL-1/2/4↓

*Note:* ++ = excellent BBB crossing, +/- = lower CNS concentrations than in peripheral blood. BBB, blood-brain barrier; BDNF, brain-derived neurotrophic factor; COX, cyclooxygenase; IFN, interferon; IL, interleukin; MTX, methotrexate; NAC, *N*-acetylcysteine; NF-κβ, nuclear factor-κβ; PG, prostaglandin; TNF, tumor necrosis factor.

### Inclusion

Consensus on the studies included was reached on the basis of the following criteria:

1. Randomized, double-blind, placebo-controlled studies regarding augmentation of antipsychotic medication with an anti-inflammatory agent listed in [table 1](#).
2. Patients included had a diagnosis of a schizophrenia spectrum disorders (schizophrenia, schizophreniform disorder, or schizoaffective disorder), according to the diagnostic criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-III, DSM-III-R, DSM-IV, and DSM-IV-TR or International Classification of Diseases, 9th or 10th Revision).
3. Studies reported sufficient information to compute common effect size (ES) statistics of change scores, ie, means and SDs, exact  $P$ ,  $t$ , or  $z$  values<sup>31,32</sup>, or corresponding authors could supply these data upon request. Studies providing only posttreatment data were not included.

Crossover studies were not excluded in order to obtain as much information as possible. Antipsychotic, antidepressant, and mood-stabilizing agents were excluded from the search because their well-known efficacy on symptom severity would confound the results. Studies that were only published as abstracts were included after contacting the authors for more detailed information. One study that was double blind and placebo controlled was excluded because no data were given on baseline parameters, and dosing was not clear.<sup>33</sup>

### Outcome Measures

The primary outcome measure was the mean change in total score on the Positive and Negative Syndrome Scale (PANSS) or the Brief Psychiatric Rating Scale. Data of the last observation carried forward analysis were used when provided. If only data of completers analyses were given, these data were used instead. Two reviewers independently extracted data from the papers, any disagreements were resolved by consensus.

### Statistical Analyses

Standardized differences were calculated from the mean differences (placebo vs augmentation) of the change score (end of treatment minus baseline) means and SDs.<sup>34</sup> When possible, change scores were used instead of pretreatment and posttreatment scores in order to avoid overestimation of the true ES because of the pre-post treatment correlations. When only exact  $F$  or  $P$  values for main effect of treatment group (augmentation or placebo) were provided, these data were used. All standardized differences were calculated twice independently from the original articles to check for errors. Standardized differences of studies were pooled in

meta-analyses to obtain mean standardized differences for primary outcome measures. Hedges's  $g$ <sup>35</sup> was used to quantify the mean standardized differences of combined studies using a random model. A homogeneity statistic,  $I^2$ , was calculated to test whether the studies could be taken together to share a common population ES.<sup>36</sup> High heterogeneity (ie,  $I^2 \geq 50\%$ ) indicates heterogeneity of the individual study ESs, which poses a limitation to a reliable interpretation of the results. Values of  $I^2$  between 30% and 50% were considered moderate. Mean standardized differences with a  $P$  value smaller than .05 were considered significant. All standardized differences were computed using Comprehensive Meta-Analysis Version 2.0

## Results

### Search

Our search yielded 26 trials that fulfilled all inclusion criteria. These studies provided information on the efficacy on symptom severity of the following components: aspirin, celecoxib, davunetide, fatty acids such as eicosapentaenoic acids (EPA) and docosahexaenoic acids (DHA), estrogens, minocycline, and NAC. The results for each component are provided in [figure 1](#).

### Aspirin

Aspirin is a NSAID that irreversibly inhibits cyclooxygenase-1 (COX-1) and modifies activity of COX-2, thereby suppressing production of thromboxanes and prostaglandins, which are key players in the inflammatory process.<sup>37,38</sup> Aspirin also reduces hypothalamic-pituitary-adrenal axis response.<sup>39</sup>

Aspirin does not readily cross the blood-brain barrier (BBB), and levels in the CNS are lower than that in peripheral blood.<sup>40</sup> Two studies provided aspirin to patients with schizophrenia in addition to their standard treatment. Laan et al (2010)<sup>41</sup> included patients who were ill for less than 10 years. Because the study by Weiser et al is only published as an abstract, no exact data on duration of illness are provided. Both studies applied 1000 mg of aspirin daily and treatment duration was 3<sup>41</sup> and 4 months.<sup>42</sup> The mean weighted ES was 0.3, with the 95% CI: 0.06–0.537. Heterogeneity was low ( $I^2 = 0\%$ ) ([figure 2](#)).

### Celecoxib

Celecoxib, another NSAID, is a selective COX-2 inhibitor, which has few other actions besides its anti-inflammatory and analgesic actions. It blocks COX-2-mediated vascular permeability, thus preventing extravasation of proinflammatory cells, proteins, and enzymes, which mediate the local inflammatory response leading to edema.<sup>43</sup> It is a small molecule that easily passes the BBB.<sup>44</sup>

Five studies added celecoxib to standard antipsychotic treatment. Only one of them<sup>45</sup> restricted inclusion to first-episode psychosis (FEP) patients. All these studies provided a dose of 400 mg to the patients, and duration of treatment was relatively short, varying from 5 to 11 weeks.<sup>46-49</sup> Results were very heterogeneous, ranging from

strong negative to strong positive effects. The study by Rappard and Muller (2004)<sup>47</sup> was only published as an abstract. The mean weighted ES was 0.15, which is not significant. The 95% CI ranged from -0.669 to 0.959, and heterogeneity was high,  $I^2 = 93\%$ . The only study in FEP yielded a positive result (figure 3).

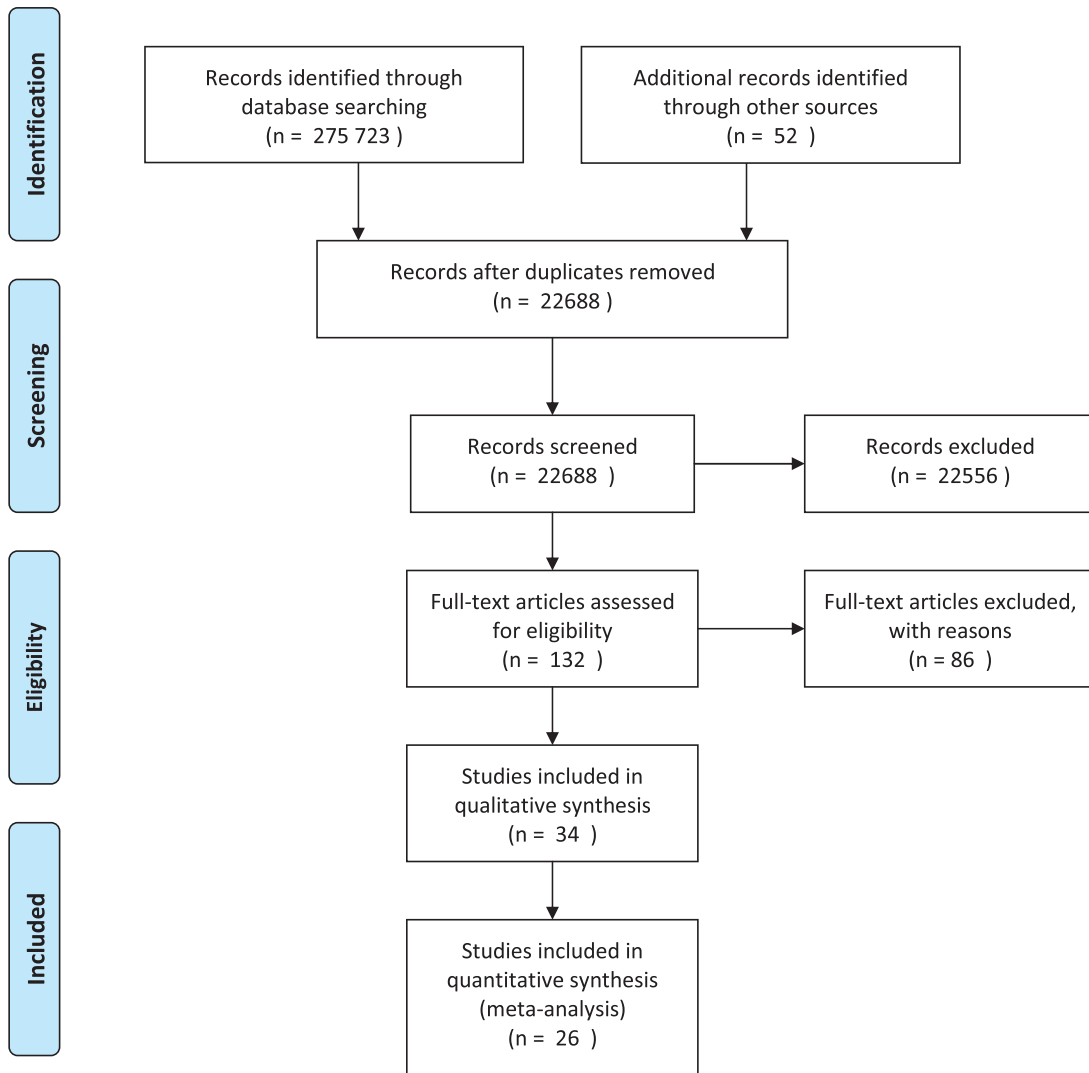


Fig. 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses 2009 flow diagram.

## Aspirin augmentation

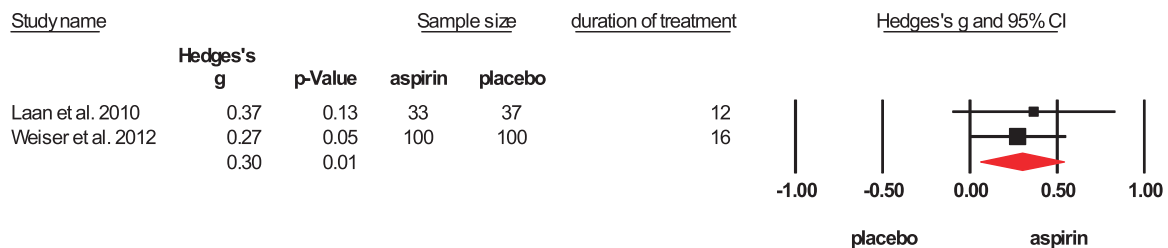


Fig. 2. Aspirin augmentation. Black square = individual effect size of a study, diamond symbol= mean weighted effect size.

*Davunetide*

Davunetide is the smallest active part of activity-dependent neuroprotective protein, which can stabilize microtubuli and may improve neurite outgrowth.<sup>50</sup> Davunetide also reduces the TNF- $\alpha$  production of activated microglia cells. It easily passes the BBB. One study provided davunetide in addition to standard treatment to patients with chronic schizophrenia.<sup>51</sup> Two different doses (5 and 30 mg) were provided for 3 months. Both doses did not improve symptom severity, and mean weighted ES was  $-0.23$  (95% CI:  $-0.65$  to  $0.19$ ,  $I^2 = 0$ ) (figure 4).

*EPA and DHA Fatty Acids*

Fatty acids, especially the EPA and DHA, also have mild anti-inflammatory aspects because they decrease serum interleukin-1 $\beta$  (IL-1 $\beta$ ), TNF- $\alpha$ , and interferon- $\gamma$  levels in addition to several other actions such as neuroprotective aspects,<sup>52,53</sup> modulation of membrane fluidity, synaptic plasticity, and effects on dopaminergic, serotonergic, and glutamatergic neurotransmission.<sup>52,54</sup> So far, 6 studies added EPA and 1 study added DHA fatty acids to antipsychotic treatment for patients with schizophrenia.<sup>55-60</sup> From the large study of Peet and Horribin<sup>60</sup> only the subset on clozapine using 2 mg EPA could be included. Two of them<sup>56,59</sup> included only FEP. The study by Fenton et al<sup>55</sup> used 3g daily, the others studies provided 2 g/day. The mean weighted ES

was  $0.09$ , which was not significant (95% CI:  $-0.16$  to  $0.35$ ). Heterogeneity was low with  $I^2 = 26.6$  (figure 5).

*Estrogens*

Estrogens, especially 17 $\beta$ -estradiol (E2), also have mild anti-inflammatory properties by ways of reducing TNF- $\alpha$  and NO<sup>25</sup> in addition to many other actions such as reducing antioxidative stress, controlling energy balance and glucose homeostasis, and influencing dopaminergic neurotransmission.<sup>25</sup> Seven studies provided estrogen in addition to standard treatment for patients with schizophrenia.<sup>61-66</sup> Six studies included only females, and 1 study<sup>65</sup> included only males. Six studies applied the estrogen (ethinyl)estradiol, and 1 study administered estrone.<sup>63</sup> Estrogen doses ranged from 0.05mg/d (patch) to 2mg/d (orally). One of the studies restricted inclusion to FEP.<sup>61</sup> One study reported a very large ES of 3.6 and was regarded as an outlier (see figure 6a).<sup>66</sup> When this outlier was excluded (figure 6b), a mean weighted ES of 0.51 was retrieved, which was significant (95% CI: 0.043-0.972). Among these studies, the study in FEP showed the highest ES. Lowest ES was obtained in the male study and in the study applying estrone. Heterogeneity was high ( $I^2 = 69\%$ ) but dropped to moderate when the study in males was excluded.

*Minocycline*

Minocycline is a broad-spectrum tetracycline antibiotic that easily crosses the BBB and has a strong inhibitory

## Celecoxib augmentation

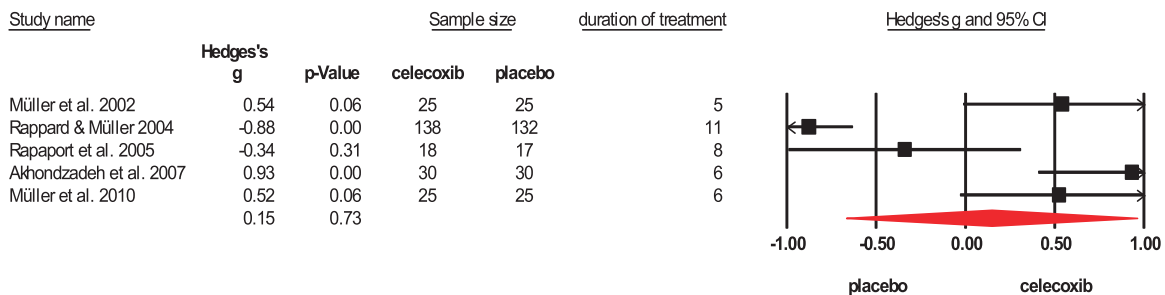


Fig. 3. Celecoxib augmentation. Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

## Davunetide augmentation

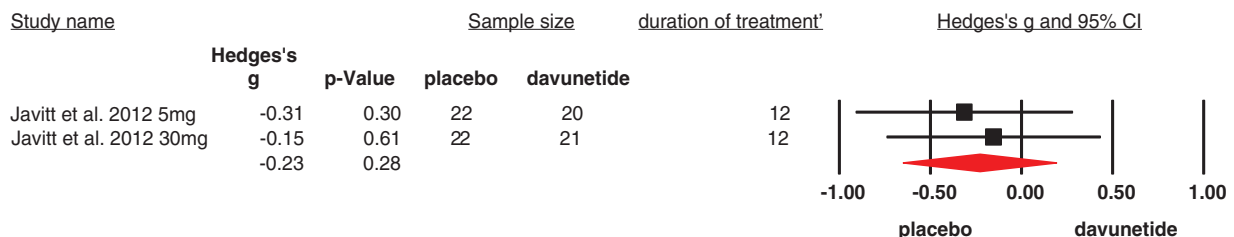


Fig. 4. Davunetide augmentation. Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

## EPA/ DHA Fatty acids augmentation

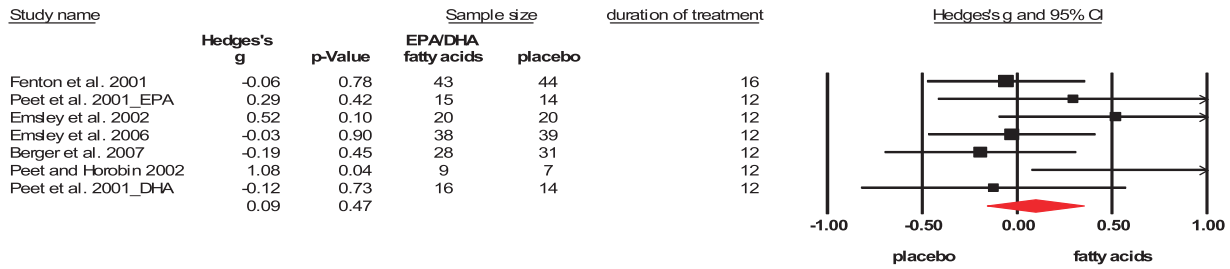
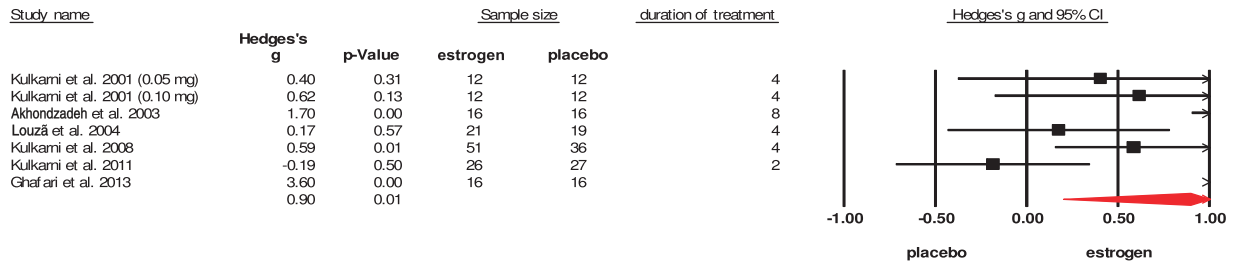


Fig. 5. Eicosapentaenoic/docosahexaenoic fatty acids augmentation. Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

## Estrogen augmentation

(a)



## Estrogen augmentation

(b)

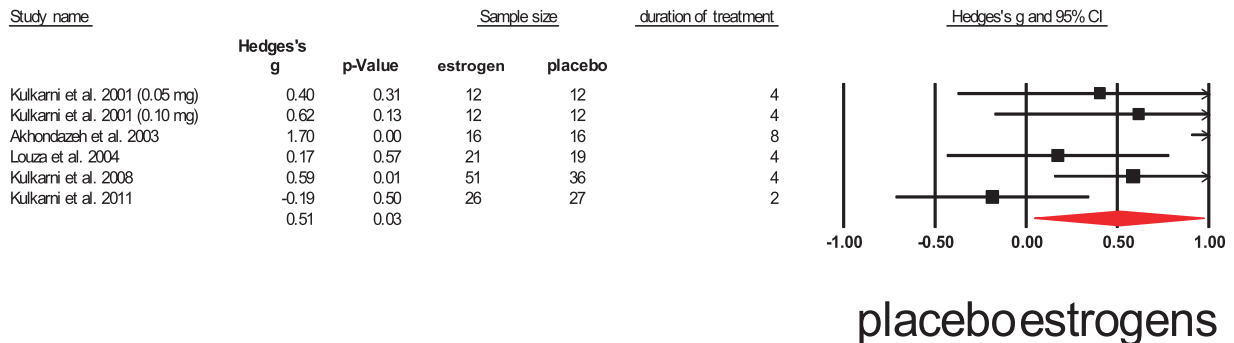


Fig. 6. Estrogen augmentation. (a) Augmentation with estrogen (including outlier). (b) Augmentation with estrogen (outlier removed). Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

effect on microglia cells.<sup>24</sup> Three studies assessed the effect of minocycline addition to antipsychotic treatment. All studies used a relatively high dose of 200 mg and long duration of treatment, ranging from 4 to 12 months. The studies by Levkovitz et al<sup>67</sup> and Chaudhry et al<sup>68</sup> included only FEP. The study by Weiser et al<sup>42</sup> is not published yet, data are used from an abstract. The Chaudhry et al study consisted of 2 smaller trials performed in Pakistan and Brazil that are presented separately. The results of these 3 studies are very heterogeneous and, with the exception of the small Pakistan trial from Chaudhry et al, do not show a beneficiary effect on symptom severity. When combined in

meta-analysis, the mean weighted effect was 0.22, which was not significant (95% CI: -0.39 to 0.82), and heterogeneity was high,  $I^2 = 83%$  (figure 7).

### N-acetylcysteine

NAC has clear anti-inflammatory properties by inhibiting the inflammatory cytokines TNF- $\alpha$ , IL-1 $\beta$ , and IL-6, but is also the precursor of glutathione, the main antioxidant of the human body.<sup>69</sup> NAC is neurotrophic and influences glutamatergic and dopaminergic neurotransmission.<sup>70</sup> NAC is small and easily passes the BBB.<sup>71</sup> Only one study assessed the influence of NAC addition on

symptom severity in patients with schizophrenia.<sup>72</sup> This study included chronic patients and provided 2 g of NAC for 6 months to the patients. A significant positive influence on total symptom severity was observed with a mean weighed effect of 0.45 (95% CI: 0.112–0.779) (figure 8).

*Effects of Anti-inflammatory Agents on Cognitive Functioning*

For aspirin, Laan et al<sup>41</sup> found no significant effect on cognition assessed with the Rey Auditory Verbal Learning Test, the HQ Continuous Performance Test, the Purdue Pegboard Test, and the Trail Making Test. For celecoxib, no data on cognitive tests were reported in the above-mentioned studies, but a positive effect was noted on the cognition factor of the PANSS.<sup>73</sup> For davunetide, a positive effect on skills was noted on the UCSD Performance-Based Skills Assessment, while there was no effect measured with the Matrics Consensus Cognitive Battery.<sup>51</sup> For EPA and DHA fatty acids, only Fenton et al (2001)<sup>55</sup> investigated cognition but found no effect using the Repeatable Battery for the Assessment of Neuropsychological Status. For estrogens, no cognitive data were assessed in the above-mentioned studies. For minocycline, 2 studies also assessed efficacy on cognitive tests, both of them using the Cambridge Neuropsychological Test Automated Battery (CANTAB), and 1 study<sup>67</sup> found improved executive functioning with

study progression ( $F = 1.6, P < .05$ ), whereas the second study (Chaudhry et al<sup>68</sup>) found no difference with placebo. In the trial investigating efficacy of NAC in schizophrenia, no cognitive tests were applied.

**Discussion**

We quantitatively reviewed the efficacy of various anti-inflammatory agents to reduce symptom severity in patients with schizophrenia. We could include data from 26 randomized placebo-controlled double-blind studies applying 7 different agents. The results of aspirin addition to antipsychotic treatment seem promising, as does the addition of estrogens and NAC. On the other hand, addition of celecoxib, minocycline, davunetide, and EPA or DHA fatty acids did not show a beneficial effect. It is important to note that the 3 agents that significantly improved symptom severity are all very broadly active substances, and it is unsure if the beneficial effects on symptom severity are indeed mediated by their anti-inflammatory aspects.

*Effects on Symptom Severity*

Aspirin showed a low to moderate, but significant effect when applied for 3 or 4 months in 2 studies including 270 patients using a dose of 1000mg/d.<sup>41,42</sup> Both studies did not limit inclusion to FEP patients.

**Minocycline augmentation**

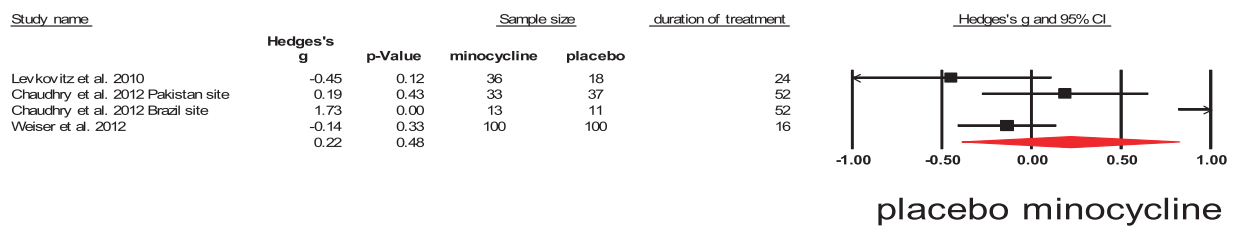


Fig. 7. Minocycline augmentation. Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

**NAC augmentation**

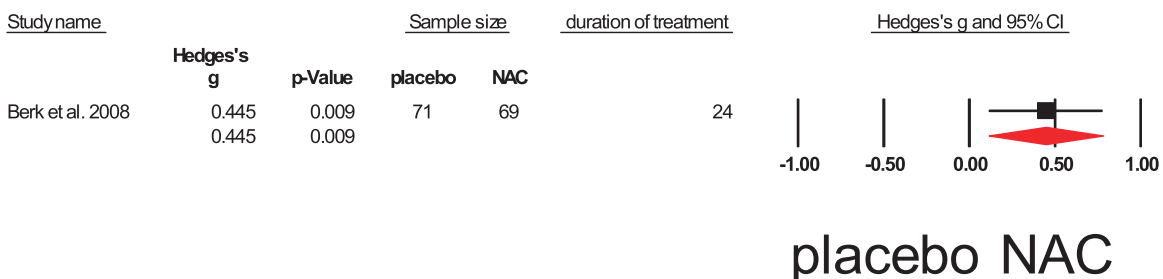


Fig. 8. N-acetylcysteine augmentation. Black square = individual effect size of a study, diamond symbol = mean weighted effect size.

Celecoxib, which is a more specific anti-inflammatory agent that crosses the BBB more readily, did not show overall efficacy in 465 patients, but this might be related to the relatively short duration of treatment of these trials (mostly 5–8 wk, only one study provided celecoxib for 11 wk). However, the studies with longer duration of treatment did not show better efficacy. The only study that provided celecoxib to FEP patients<sup>73</sup> did show a positive effect. It can, therefore, not be excluded that celecoxib is effective only in FEP patients.

Two previous meta-analyses reviewed efficacy of NSAIDs for schizophrenia patients and reported modest efficacy, which reached significance in the first<sup>20</sup> and borderline significance in the second review.<sup>74</sup> We here show that celecoxib and aspirin may differ in their efficacy, with aspirin showing better results. However, the 2 studies on aspirin included a total of 270 patients only and the mean effect size may change when more studies become available.

The studies that used davunetide and EPA or DHA fatty acids, all 3 agents that have mild anti-inflammatory and neuroprotective actions, did not show an overall positive effect. All studies were of longer duration (12 wk and one study 16 wk). From the 2 trials that provided fatty acids to FEP patients, one showed a positive effect, whereas the other trial showed a negative effect.

Estrogen augmentation showed a significant mean effect in 6 studies including 262 patients already for relatively short duration of study (ranging from 2 to 8 wk). The single study that restricted inclusion to FEP had the largest ES. However, estrogens act on many different ways in the brain and may cause their effect by mechanisms unrelated to inflammation, eg, by affecting angiotensin and dopamine neurotransmission.<sup>75,76</sup>

Minocycline is a strong inhibitor of microglia cell activation<sup>24</sup> and may, therefore, be expected to have potent effects on symptom severity. This component was provided in a relatively high dose of 200 mg for a relatively long time (4–12 mo), including 2 studies that restricted inclusion to FEP patients, but the results in these 348 patients were not significant although heterogeneity was high. However, it is too early to take this as evidence against the inflammation hypothesis of schizophrenia because several trials that used minocycline in patients with rheumatoid arthritis<sup>77</sup> and amyotrophic lateral sclerosis<sup>78–80</sup> showed a trend towards symptom aggravation rather than improvement, while these 2 diseases are clearly associated with increased proinflammatory status in the brain. Several authors report that minocycline can trigger autoimmune diseases such as lupus erythematosus, arthritis, thyroiditis, and hepatitis,<sup>81–88</sup> suggesting that minocycline may also worsen proinflammatory and autoimmune processes.

The use of NAC for 24 weeks in a study including 140 patients showed a positive result with a moderate ES of 0.45. Because this study included more chronic patients, a study in FEP patients might show even better results.

Because the positive results of NAC rely on a single randomized controlled trial, replication is needed before we can draw any conclusion.

### *Effects on Cognition*

Only 5 of the 26 included studies provided data on cognitive test batteries and from these, 4 found no effects on cognition and 1 study observed a significant effect of minocycline. Heterogeneity of cognitive tasks employed was too great to make a quantitative review of these effects.

### *Side Effects*

Reconsidering the 3 agents that yielded positive results in this study, it is worthwhile to compare their side effects and safety profile. To start with aspirin, it is known that application of aspirin should be combined with gastric protection because of the risk of gastrointestinal bleeding. This is not an uncommon phenomenon and, therefore, should be seriously considered and monitored during treatment. On the other hand, aspirin also has cardioprotective properties, which can be a benefit, especially in patients with metabolic syndrome.

Estrogens are not safe for longer application than 1–2 months, unless combined with progesterone. In addition, estrogens are not suitable for men. Raloxifen or tamoxifen may be safe alternatives, but efficacy of these substances remains to be determined.

NAC has very few side effects, and next to its more favorable side effect profile than aspirin, it can even be administered during pregnancy. NAC may have additional benefits in schizophrenia, such as decreasing addiction<sup>89–93</sup> and increasing glutathione levels, thereby increasing scavenger potential.

### **Limitations**

An important limitation is that the field of augmentation with anti-inflammatory components in schizophrenia is still in its infancy, and only few studies have been performed. Many components with strong anti-inflammatory potency, such as the glucocorticosteroids, have not been tried in patients with schizophrenia. Nor have the statins, another promising group of components, which are well tolerated and have anti-inflammatory actions on the brain in addition to their well-known ability to prevent or reduce metabolic syndrome.

### **Conclusion**

At this point, it is too early to make conclusions on the efficacy on symptom severity of schizophrenia of augmentation with anti-inflammatory agents. Some beneficial effects of aspirin, NAC, and estrogens were observed, while addition of celecoxib, EPA/DHA fatty acids, davunetide, and minocycline did not show efficacy. The fact that aspirin, NAC, and estrogens have many other effects apart from their anti-inflammatory actions that can also



improve symptoms of schizophrenia makes it even less certain that reducing the proinflammatory status of the brain improves clinical status. Efficacy on cognition is currently not supported by the data. Taken together, there is some preliminary evidence for efficacy of anti-inflammatory agents on symptom severity in patients with schizophrenia, but further trials are needed.

### Acknowledgments

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