

RESEARCH ARTICLE

Neurobehavioral Potential of Cod Liver Oil in Experimental Depressed Rats: Insights into Ingestive, Cognitive, and Motor Functions

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Abstract: Depression-induced variations in the metabolic and neurological components have been given more attention in research. The chronic unpredictable stress rodent model mimics daily human life stressors. This study aimed to elucidate the defensive role of cod liver oil on memory, behavioral variations, and sensorimotor coordination in the Wistar rat model of comorbid depression. Wistar albino rats were categorized into the control group and the experimental group. Based on the stress exposure, cod liver oil, and antidepressant drug treatment, the rats were categorized into various subgroups. The treatment procedure and the stress exposure were done for 15 days. The ingestive behavior was monitored daily, and the body weight changes were also noted. The behavioral, cognitive, and sensorimotor coordination was completed on the 16th day. Cod liver oil stabilized the ingestive behavior, improved sensory motor coordination, and reduced anxiety behavior. The present results confirmed that cod liver oil was an efficient antidepressant. The role of cod liver oil as an antidepressant agent could be due to the molecular and cellular mechanisms. This could aid in investigating possible treatments that could target depression and anxiety through a dietary approach.

Keywords: Cod Liver Oil, Chronic Unpredictable Stress, Rotarod, Depression, Behavior

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Introduction

The prevalence of depression has been rising both globally and nationally, significantly impacting individuals' quality of life [1, 2]. The United Nations' Sustainable Development Goals (SDG) emphasize good mental health as a critical component, particularly under SDG-3 [3]. The link between adverse life events and their psychological consequences has been recognized by physicians for over four centuries [3]. Stress plays a prime role in neuropathological disorders [4, 5].

Depending on the duration of exposure, stressors are categorized as acute or chronic. Chronic stress, in particular, has wide-ranging health effects, contributing to neuropsychiatric disorders and disruptions in immune function [6]. Long-term stress also leads to impairments in memory [6-7]. Although numerous protective agents have been studied, an effective and safe therapeutic intervention for managing stress remains elusive. Stress-induced alterations in mood and anxiety have

inspired researchers to develop experimental animal models to simulate behavioral and neurobiological changes, with the goal of informing therapeutic strategies for stress-related psychopathologies in humans.

Rodent models have proven invaluable for studying human psychopathology under stress conditions. The Chronic Unpredictable Stress (CUS) model helps to evaluate depression and anxiety-like behaviors in rodents [8, 9]. Functional and structural alterations in the hippocampus are linked to stress responses [10, 11]. Stress-induced generation of free radicals has been associated with the pathogenesis of neuropsychiatric disorders [11, 12]. Chronic stress has also been shown to impair hippocampal-dependent cognition and exhibit region-specific effects within the brain [13, 14]. Neuroendocrine, neurochemical, and genetic factors contribute to individual differences in stress perception and response. To date, no pharmaceutical intervention has been developed that effectively targets specific brain tissues.

Natural agents through dietary mode, that could safely respond to the harmful effects of stress have become a key area of interest. Cod Liver Oil (CLO) is one such dietary supplement rich in long-chain omega-3 fatty acids, which includes eicosatetraenoic acid (EPA) and docosahexaenoic acid (DHA) along with vitamins A and D [15]. DHA is known to foster hippocampal neurogenesis, synaptic plasticity, and membrane fluidity. All these mechanisms support learning and memory processes [13]. EPA reduces pro-inflammatory cytokine production and decreases stress-mediated activation of the hypothalamic-pituitary-adrenal (HPA) axis, which is often disrupted in depression. Additionally, vitamins A and D possess antioxidant and immunomodulatory properties that protect neuronal tissues from oxidative injury while modulating neurotrophic signaling pathways involved in mood regulation. Nutrient-rich foods containing high levels of antioxidants and vitamins have shown promising neurological benefits [16, 17].

Even though various evidences support nutritional neuroscience, the medicinal effectiveness of CLO in stress-induced depressive behaviors and cognitive decline remains underexplored. Therefore, identifying safe and effective neuroprotective interventions is essential for combating chronic stress-related brain dysfunction. This study aims to evaluate the antidepressant and neuroprotective effects of cod liver oil in a Wistar rat model subjected to chronic unpredictable stress, with specific focus on ingestive behavior, affective behavior, cognition, and sensorimotor coordination.

Materials and Methods

Ethical Approval

The protocol was submitted to the institutional animal ethical review committee and all the experimental procedures was commenced after the approval has been received (KMC/MNG/IAEC/16-2019). All the guidelines as per the animal ethical committee has been followed .

Animals

Wistar strain albino rats (120-160 grams), were housed in standard polypropylene cages with free access to food and water. Temperature ($28 \pm 2^\circ\text{C}$) and relative humidity of $50 \pm 5\%$. was maintained

The Chronic Unpredictable Stress (CUS)

This model was employed for 15 consecutive days, based on previously established protocols [17]. Stressors were administered at varying times and randomized sequences to reduce predictability and habituation.

Drug Administration

CLO was purchased commercially (Sea Cod brand, India) and administered orally at a dose of 5 mL/kg body weight, and imipramine (a standard antidepressant) was given orally at 5 mg/kg body weight. Dosages were selected based on validated prior studies [17].

Experimental Groups

A total of six animals were used in each group (n=6). Animals were divided into control and experimental groups as follows:

Control Groups (CUS-unexposed):

Group I - Normal Control: No stress exposure or treatment.

Group Ia - CLO Control: CLO administered without stress exposure.

Group Ib - Antidepressant Control: Imipramine administered without stress exposure.

Experimental Groups (CUS-exposed for 15 days)

Group II - CUS Only: Exposed to chronic unpredictable stress with no treatment.

Group IIa - CUS + CLO: Exposed to CUS and treated with CLO.

Group IIb - CUS + Antidepressant: Exposed to CUS and treated with imipramine.

Group IIc - CUS + CLO + Antidepressant: Exposed to CUS and treated with both CLO and imipramine. The following parameters were noted.

Parameters

Body Weight

The body weight of the animals was recorded in the animal weighing balance. The fractions of weights were expressed to the nearest gram unit.

Food Intake

Food intake was studied by keeping food pallets weighed in the food cup every day between 9 to 10 AM. After one day, the left-over food was collected and weighed. The difference between the food provided and the left over was noted as the food consumed by the rat in one day.

Water Intake

Known volume of water was filled in plastic bottles and placed in the bottle holder. The nozzle of the bottle was passed into the cage for the convenience of the rats to lick it up. The remaining water in the bottle was measured after 24 hours and noted. The water consumption was measured everyday between 9 and 10 AM.

Open-Field Test

Used to assess anxiety, emotional, and exploratory behavior [17-19]. Animals were placed in a brightly lit rectangular open field (100 × 100 cm; wall height: 40 cm). The floor was divided into 25 squares (5 × 5 grid). A 100-watt bulb positioned 150 cm above the center provided illumination. Each rat was placed in a corner, and activity was recorded for 5 minutes. The number of central and peripheral square entries was documented.

Object Recognition TEST

This test helps in assessment of memory. The apparatus consisted of a plywood box (28 × 41 × 18 cm). Locomotor activity was recorded using a video tracking mobile phone device. Objects exploration was counted by the experimenter. Four training sessions and one test session were performed for each animal. Each exposure lasted for five minutes with a 3-minutes break between each trial, the rats were placed in the respective home cages. During training test, two similar objects (width: 3 cm, height: 8 cm), were placed in the box. The rats were made to explore freely. During the test session, one of the object was substituted by a novel object and duration of time that animal explored the novel object and the familiar object was noted as per the experimental procedure. Placement of the nostrils near the object at a distance of ≤ 2 cm, keeping the forepaws on the objects was noted as exploratory behavior. Objects were washed with 70% ethanol after each trial to avoid smell clues. The exploration time and discrimination index was calculated as per the previous studies behavior [17-19].

Forced Swimming Test

Cylindrical tank (20 cm diameters) was filled with water up to 30cm. Temperature of the water was 23-25°C. Rats were individually placed into the cylinder and timer was set on, after five minutes of swimming, rats were taken out from water and placed in their home cage after towel drying. Water was refilled in cleaned cylinder for subsequent rats. The time that each rat spent in movement was measured. Mobility time was subtracted from test time denoting the immobility time behavior [17-19].

Rotarod Test

A trial was conducted by placing the animals in rotarod at 10 rpm for 60 seconds and observed for 'forward walking' to keep the balance. The same procedure was repeated for two trials separated by 5 minutes intervals. In the experimental session, the same speed was kept and the latency to fall was calculated behavior [17-19].

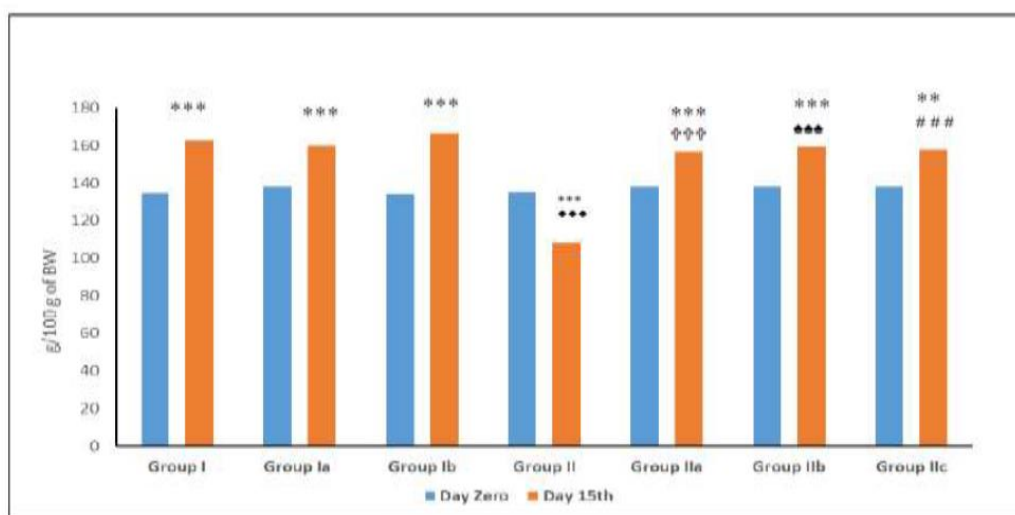
Statistical Analysis

Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test for multiple group comparisons. Data are expressed as mean \pm SEM. $P < 0.05$ considered significant.

Results

Body Weight

Day zero did not show any significant changes when matched to its respective control groups. CUS exposure (Group II) significantly ($P < 0.0001$) reduced the body weight. When compared to CLO group (Group IIa), antidepressant (Group IIb) and combination of CLO and antidepressant (Group IIc) significantly increased ($P < 0.0001$) the body weight. No significant changes were observed in Group IIa when compared to Group IIb and Group IIc (Figure1).



*** $P < .0001$ Day Zero versus Day 15

◆◆◆ $P < .0001$ Group I versus Group II

⚡⚡⚡ $P < 0.001$ Group II versus Group IIa

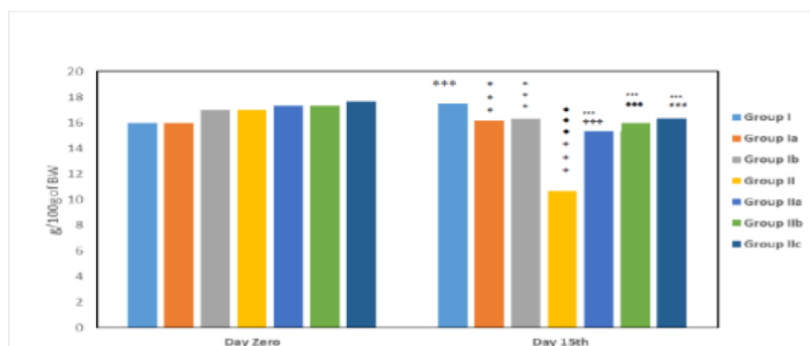
▲▲▲ $P < 0.001$ Group II versus Group IIb

$P < 0.01$ Group II versus Group II C

Fig. 1: CUS induced body weight changes in control groups and experimental groups

Food Intake

When compared to day zero, the food intake was significantly ($P < 0.0001$) on the 15th day. The food intake significantly ($P < 0.0001$) declined in CUS group (Group II) Further, CLO treatment increased ($P < 0.0001$) the food intake (Group IIa). Similar results were observed in Group IIb and Group IIc (Figure 2).

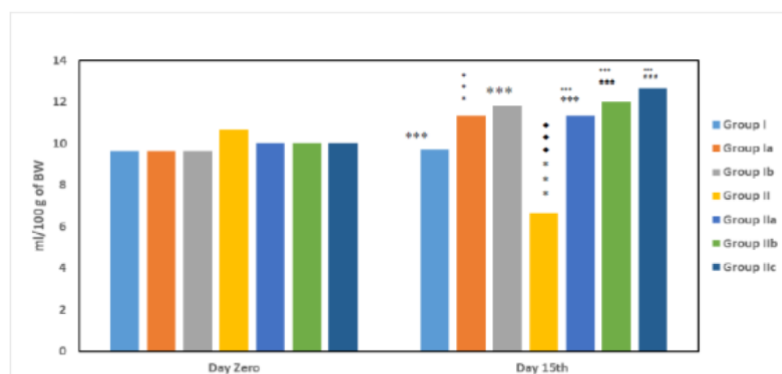


***P < .0001 Day Zero versus Day 15
 ***P < .0001 Group I versus Group II
 †††P < 0.001 Group II versus Group IIa
 ***P < 0.001 Group II versus Group IIb
 ##P < 0.01 Group II versus Group II C

Fig. 2: CUS induced changes in the food intake in control groups and experimental groups

Water Intake

The water intake in all groups on the starting day of the experiment did not show any significant changes when compared to its respective control groups. On the 15th day, water intake significantly increased ($P < 0.0001$). CUS exposure (Group II) significantly ($P < 0.0001$) decreased the water intake. Group IIa, Group IIb and combination group (Group IIc) increased water intake ($P < 0.0001$). (Figure 3).

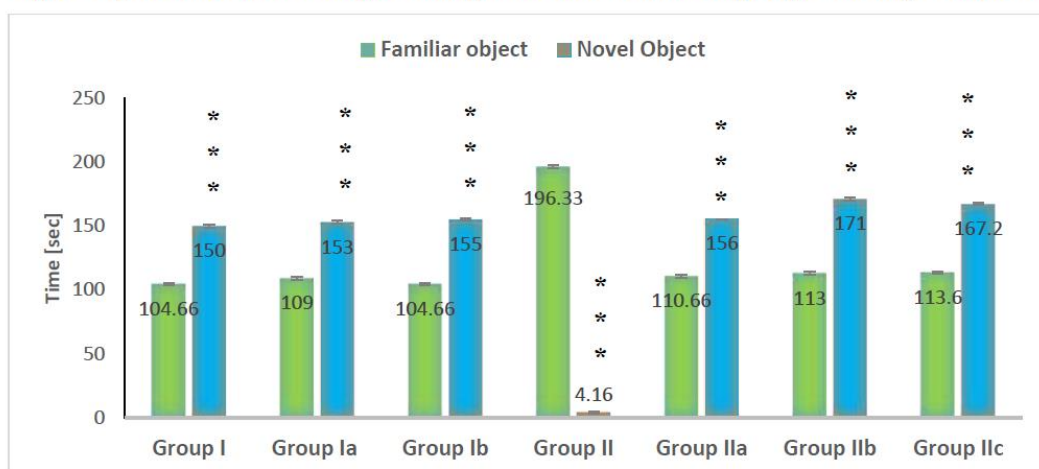


***P < .0001 Day Zero versus Day 15
 ***P < .0001 Group I versus Group II
 †††P < 0.001 Group II versus Group IIa
 ***P < 0.001 Group II versus Group IIb
 ##P < 0.01 Group II versus Group II C

Fig. 3: CUS induced changes in the water intake in control groups and experimental groups

Object Recognition Test

The time spent near the novel object in the CUS significantly decreased ($P < 0.001$) when compared control groups. However, treatment of the stressed rats (Group IIa), Antidepressant (Group IIb) and in combination increased ($P < 0.001$) the time spent near the novel object. CUS showed a significant decline in the ($P < 0.0001$) the discrimination index (Figure 4).

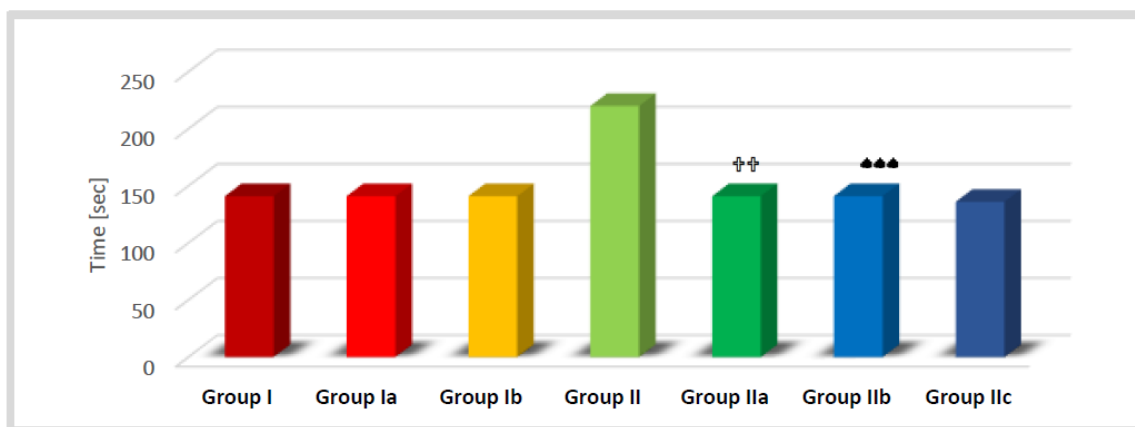


P<0.001* : Familiar object versus Novel object**

Fig. 4: Exploration time in object recognition test in control groups and experimental groups

Force Swimming Test

The immobility time was significantly more in the chronic unpredictable stress group (P<0.001) and it decreased significantly (P<0.001) in the Group IIa, Group IIb and Group IIc (Figure 5).



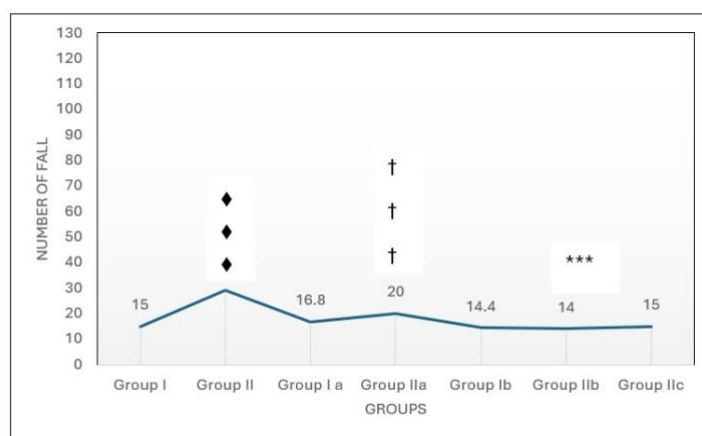
***P< .0001 Group I versus Group II
 ††P < 0.01, †††P < 0.001 Group II versus Group IIa
 ***P < 0.001 Group II versus Group IIb
 ## #P < 0.01 Group II versus Group II C

Fig. 5: Force Swimming test in control groups and experimental groups

Rotarod Test

The rotarod test results demonstrated that exposure to chronic unpredictable stress (Group II) produced a marked impairment in motor coordination, as indicated by a significant increase in the number of falls compared to the normal control group (Group I) (P < 0.0001). Treatment with Cod Liver Oil (Group IIa) significantly (P < 0.0001) reduced the number of falls, Antidepressant treatment (Group IIb) showed a more pronounced effect, with the number of falls reduced to near control

levels. Similarly, the combination of Cod Liver Oil and antidepressant (Group IIc) restored motor performance close to normal, comparable to the control group. (Figure :6).



◆◆◆ p < 0.0001 : Group I versus Group II
 ††† p < 0.001 : Group II versus Group IIa
 *** p < 0.001 : Group II versus Group IIb

Fig. 6: Effect of cod liver oil on rotarod test in control groups and experimental groups

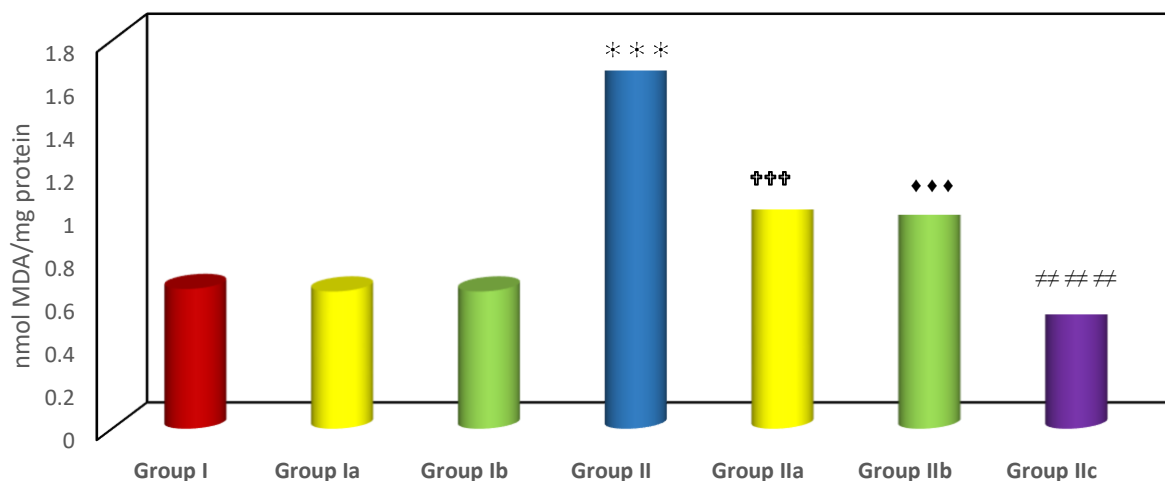


Fig. 7: Effect of cod liver oil on cerebellar lipid peroxidation level in control and experimental groups

*** P < 0.0001; Group I vs Group II

†††P < 0.0001; Group II vs Group IIa

◆◆◆ P < 0.0001; Group II vs Group IIb

####P < 0.0001; Group II versus Group IIc

Lipid peroxidation levels in the cerebellum showed a significant variation across all groups (one-way ANOVA). The CUS-exposed group (Group II) exhibited a marked increase in MDA levels compared to the normal control (P < 0.0001), indicating pronounced oxidative stress following chronic unpredictable stress exposure. Treatment with CLO (Group IIa) and imipramine (Group IIb) each produced a significant decrease in lipid peroxidation (p < 0.0001), suggesting substantial attenuation of stress-induced oxidative damage. Notably, combined administration of CLO and imipramine (Group IIc) yielded the most

pronounced reduction ($p < 0.0001$), approaching near-normal levels. These findings indicate that both CLO and imipramine exert neuroprotective antioxidant effects in the cerebellum, with additive efficacy when co-administered (Figure 7).

Discussion

Long-term exposure to stress is strongly associated with the enhancement of depressive and anxiety disorders and is known to cause extensive neuroendocrine and neurochemical disturbances [1]. The hippocampus, prefrontal cortex, and amygdala are more vulnerable, where prolonged stress causes disturbances in synaptic plasticity, reduced neurogenesis, and increased neuroinflammatory responses [20,21]. The Chronic Unpredictable Stress (CUS) model mimics all these behavioral and cognitive alterations in rodents, making it a robust model for investigating stress-induced neuropathology [17].

Ingestive behaviour and body weight serve as sensitive, non-invasive physiological biomarkers of stress, offering insight into its metabolic consequences. In our study, Chronic Unpredictable Stress (CUS) significantly reduced food intake and body weight, consistent with prior findings [22]. This reduction may be attributed to increased metabolic demands, impaired digestion, and elevated adrenal hormone secretion. The stress-induced release of corticotropin-releasing factor is known to suppress appetite, supporting our observations. Interestingly, CLO supplementation during CUS reversed the decline in ingestive behavior. CLO has been linked to improved mood and a reduced incidence of mental health disorders [21,23]. The restoration of food intake and body weight in treated rats suggests a potential antistress role of CLO.

The forced swimming test is commonly used to screen antidepressant activity. In this test, rats are placed in water and typically become immobile after an initial struggle. Immobility is considered a behavioral marker of despair. In our study, stress exposure increased immobility time, indicating depressive-like behavior. However, CLO supplementation reduced immobility time, reflecting its antidepressant potential. This response was comparable to the imipramine-treated group.

Exploratory behavior, another indicator of anxiety-like states, was impaired by CUS. Stressed rats showed reduced activity and preferred the periphery in the open field test—an indication of heightened anxiety. CLO-treated rats exhibited increased exploration and greater time in the central area, suggesting anxiolytic effects. A negative discrimination index after CUS indicated impaired memory. CLO supplementation improved memory performance and reduced anxiety-like behavior similar to imipramine treatment. These findings suggest that chronic stress may trigger oxidative stress and reactive oxygen species (ROS) production, impairing memory. The cognitive-protective effects of CLO may stem from its antioxidant properties.

The rotarod test assessed sensorimotor coordination. The number of falls in stressed rats was higher. Treatment with CLO reduced the number of falls, demonstrating its potential role in restoration of motor balance. This is further supported by the decline in lipid peroxidation levels in the cerebellum. Antidepressants like imipramine are commonly used for treating stress-related disorders; however, their side effects are well documented. Imipramine works by blocking the reuptake of norepinephrine and serotonin, thereby enhancing adrenergic and serotonergic neurotransmission. To validate the antidepressant potential of CLO, we included an imipramine-treated group in our study. Imipramine reversed CUS-induced changes in all parameters, consistent with our expectations. The effects of CLO were comparable to those of imipramine, further supporting CLO's role as a potential antidepressant agent [23].

The therapeutic effects observed with CLO may be associated with the synergistic actions of its key bioactive components EPA, DHA, and vitamins A and D. DHA is essential for neuronal membrane fluidity and synapse formation and has been shown to increase hippocampal neurogenesis and promote BDNF signaling. EPA may decrease neuroinflammation by suppressing pro-inflammatory cytokines and dampening microglial activation, mechanisms known to underlie depressive pathology. Furthermore, vitamins A and D play critical roles in regulating oxidative stress responses, maintaining mitochondrial stability, and modulating HPA-axis function. Together, these components counteract stress-induced oxidative damage and restore neuronal resilience. Collectively, these findings suggest that CLO exerts its beneficial effects through integrated modulation of neuroinflammatory pathways, enhancement of hippocampal neurogenesis, stabilization of neuronal membranes, and attenuation of HPA-axis hyperactivity, thereby improving behavioral, cognitive, and motor outcomes under chronic stress.

While previous studies, including our earlier work [17], have primarily focused on the antioxidant properties of CLO and its capacity to reduce oxidative stress, the present study extends these findings by exploring the functional and behavioral correlates of such molecular protection. Specifically, this work links CLO supplementation to improvements in ingestive behavior, affective responses, memory, and motor coordination, providing a broader neurobehavioral framework for its

antidepressant potential. The inclusion of a combination group (CLO + imipramine) offers additional insight into possible pharmacodynamic interactions, suggesting that CLO may enhance antidepressant efficacy through complementary mechanisms such as modulation of hippocampal neurogenesis, suppression of neuroinflammation, and regulation of HPA-axis activity. Thus, this study advances current understanding by integrating behavioral, biochemical, and mechanistic dimensions of CLO's neuroprotective action under chronic stress conditions.

Conclusion

Our study findings suggest that CLO, a natural supplement, might possess significant antidepressant and anxiolytic properties. CLO effectively counteracted stress-induced declines in ingestive behavior, body weight, exploratory activity, memory performance producing effects comparable to the standard antidepressant imipramine. These effects may be mediated through modulation of neuroinflammatory pathways, neurogenesis, hypothalamic-pituitary-adrenal axis regulation, and promoting neurotransmitter balance particularly serotonin and dopamine systems. Given the growing interest in integrative and nutritional psychiatry, these findings could support the translational potential of CLO in preventive and adjunctive mental health strategies, especially in populations with limited access to conventional treatments. Given its accessibility and minimal side effects, CLO holds promise as a dietary adjunct in therapeutic approach in anxiety disorders the observed effects may involve multiple molecular and cellular mechanisms, warranting further research using proteomics, histopathological, and molecular techniques fully elucidating its therapeutic potential in mental health management. Further, the future research could also explore dose response relationships, long-term safety, and the efficacy of CLO in diverse models of chronic stress and depression to validate its use in clinical settings. However, limitations such as the use of a single animal model and short duration of treatment necessitate cautious interpretation until further corroborated by longitudinal and clinical studies.

Authors Contributions

Megha Gokul: Investigation

Dimple Shet: Investigation, Formal analysis, Writing - original draft

Nayanatara Arun Kumar: Conceptualization, Methodology, Investigation, Formal analysis

Rekha Durgadas Kini: Formal analysis

Vinodini NA: Formal analysis

Anupama N: Formal analysis

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Ethics

All experimental procedures were conducted in accordance with the guidelines of the Institutional Ethical Committee and all the guidelines were followed. (Approval No. KMC/MNG/IAEC/16-20 19).

Data Availability Statement

The set of data which were generated and analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Javaid, S. F., Hashim, I. J., Hashim, M. J., Stip, E., Samad, M. A., & Ahababi, A. A. (2023). Epidemiology of anxiety disorders: global burden and sociodemographic associations. *Middle East Current Psychiatry*, 30(1), 44. <https://doi.org/10.1186/s43045-023-00315-3>
2. Vikan, M., Haugen, A. S., Bjørnnes, A. K., Valeberg, B. T., Deilkås, E. C. T., & Danielsen, S. O. (2023). The association between patient safety culture and adverse events - a scoping review. *BMC Health Services Research*, 23(1), 300. <https://doi.org/10.1186/s12913-023-09332-8>
3. Sorooshian, S. (2024). The sustainable development goals of the United Nations: A comparative midterm research review. *Journal of Cleaner Production*, 453, 142272. <https://doi.org/10.1016/j.jclepro.2024.142272>
4. Dyall, S. C. (2015). Long-chain omega-3 fatty acids and the brain: a review of the independent and shared effects of EPA, DPA and DHA. *Frontiers in Aging Neuroscience*, 7, 52. <https://doi.org/10.3389/fnagi.2015.00052>
5. Joffre, C., Nadjar, A., Lebbadi, M., & Laye, S. (2020). Omega-3 fatty acids and hippocampal neuroinflammation in depression. *Current Opinion in Pharmacology*, 50, 1-6.
6. Thurston, R. C., Jakubowski, K., Chang, Y., Wu, M., Barinas Mitchell, E., Aizenstein, H., Koenen, K. C., & Maki, P. M. (2023). Posttraumatic Stress Disorder Symptoms and Cardiovascular and Brain Health in Women. *JAMA Network Open*, 6(11), e2341388. <https://doi.org/10.1001/jamanetworkopen.2023.41388>
7. Schwabe, L. (2025). Memory Under Stress: From Adaptation to Disorder. *Biological Psychiatry*, 97(4), 339-348. <https://doi.org/10.1016/j.biopsych.2024.06.005>
8. Zafar, M. S., Nauman, M., Nauman, H., Nauman, S., Kabir, A., Shahid, Z., Fatima, A., & Batool, M. (2021). Impact of Stress on Human Body: A Review. *European Journal of Medical and Health Sciences*, 3(3), 1-7. <https://doi.org/10.24018/ejmed.2021.3.3.821>
9. Pujo, J. M., Fitriani, D. Y., Ben Saad, H., Ghariani, M., Dghim, A., Mellouli, M., Burin, A., Mutricy, R., Houcke, S., Roujansky, A., Mansyur, M., Nkontcho, F., de Toffol, B., Ben Amara, I., & Kallel, H. (2023). The effects of prolonged stress exposure on the brain of rats and insights to understand the impact of work-related stress on caregivers. *Frontiers in Behavioral Neuroscience*, 17, 1288814. <https://doi.org/10.3389/fnbeh.2023.1288814>
10. Gokul, M., Arun Kumar, N., Durgadas Kini, R., Blossom, V., Kodavanji, B., Noojibail, A., Murali, N., & Vishwanath Rai, S. P. (2019). Evaluation of biomarkers of stress in chronic stress-exposed comorbid depression model Wistar rats. *Journal of Basic and Clinical Physiology and Pharmacology*, 30(5), 20180215. <https://doi.org/10.1515/jbcpp-2018-0215>
11. Blossom, V., Gokul, M., Kumar, N. A., Kini, R. D., Nayak, S., & Bhagyalakshmi, K. (2020). Chronic unpredictable stress-induced inflammation and quantitative analysis of neurons of distinct brain regions in Wistar rat model of comorbid depression. *Veterinary World*, 13(9), 1870-1874. <https://doi.org/10.14202/vetworld.2020.1870-1874>
12. Kim, E. J., & Kim, J. J. (2023). Neurocognitive effects of stress: a metaparadigm perspective. *Molecular Psychiatry*, 28(7), 2750-2763. <https://doi.org/10.1038/s41380-023-01986-4>
13. Gulyaeva, N. V. (2023). Glucocorticoids Orchestrate Adult Hippocampal Plasticity: Growth Points and Translational Aspects. *Biochemistry (Moscow)*, 88(5), 565-589. <https://doi.org/10.1134/s0006297923050012>
14. Baybutt, R. C., Standard, J. T., Dim, D., Quinn, T., Hamdan, H., Lin, D., Kunz, K., Bomstein, Z. S., Estorge, B. J., Herndon, B., Zia, H., Mansour, A., Lankachandra, M., & Molteni, A. (2022). Cod Liver Oil, but Not Retinoic Acid, Treatment Restores Bone Thickness in a Vitamin A-Deficient Rat. *Nutrients*, 14(3), 486. <https://doi.org/10.3390/nu14030486>
15. Banaszak, M., Dobrzyńska, M., Kawka, A., Górna, I., Woźniak, D., Przysławski, J., & Drzymała-Czyż, S. (2024). Role of Omega-3 fatty acids eicosapentaenoic (EPA) and docosahexaenoic (DHA) as modulatory and anti-inflammatory agents in noncommunicable diet-related diseases - Reports from the last 10 years. *Clinical Nutrition ESPEN*, 63, 240-258. <https://doi.org/10.1016/j.clnesp.2024.06.053>
16. Shet, D., Kumar, N., Gokul, M., Kini, R., Marathe, A., Kollampare, S., & Blossom, V. (2023). Protective role of cod liver oil on hippocampal oxidative damage and neuronal count in Wistar rat model of comorbid depression. *Open Veterinary Journal*, 13(4), 473. <https://doi.org/10.5455/ovj.2023.v13.i4.9>
17. Acikgoz, B., Dalkiran, B., & Dayi, A. (2022). An overview of the currency and usefulness of behavioral tests used from past to present to assess anxiety, social behavior and depression in rats and mice. *Behavioural Processes*, 200, 104670. <https://doi.org/10.1016/j.beproc.2022.104670>
18. Huang, L., Xiao, D., Sun, H., Qu, Y., & Su, X. (2022). Behavioral tests for evaluating the characteristics of brain diseases in rodent models: Optimal choices for improved outcomes (Review). *Molecular Medicine Reports*, 25(5), 183. <https://doi.org/10.3892/mmr.2022.12699>
19. Jakkamsetti, V., Scudder, W., Kathote, G., Ma, Q., Angulo, G., Dobariya, A., Rosenberg, R. N., Beutler, B., & Pascual, J. M. (2021). Quantification of early learning and movement sub-structure predictive of motor performance. *Scientific Reports*, 11(1), 14405. <https://doi.org/10.1038/s41598-021-93944-9>
20. Italia, M., Forastieri, C., Longaretti, A., Battaglioli, E., & Rusconi, F. (2020). Rationale, Relevance, and Limits of Stress-Induced Psychopathology in Rodents as Models for Psychiatry Research: An Introductory Overview. *International Journal of Molecular Sciences*, 21(20), 7455. <https://doi.org/10.3390/ijms21207455>
21. Madison, A. A., Belury, M. A., Andridge, R., Renna, M. E., Rosie ShROUT, M., Malarkey, W. B., Lin, J., Epel, E. S., & Kiecolt-Glaser, J. K. (2021). Omega-3 supplementation and stress reactivity of cellular aging biomarkers: an ancillary substudy of a randomized, controlled trial in midlife adults. *Molecular Psychiatry*, 26(7), 3034-3042. <https://doi.org/10.1038/s41380-021-01077-2>
22. DiNicolantonio, J. J., & O'Keefe, J. H. (2020). The Importance of Marine Omega-3s for Brain Development and the Prevention and Treatment of Behavior, Mood, and Other Brain Disorders. *Nutrients*, 12(8), 2333. <https://doi.org/10.3390/nu12082333>
23. Braund, T. A., Tillman, G., Palmer, D. M., Gordon, E., Rush, A. J., & Harris, A. W. F. (2021). Antidepressant side effects and their impact on treatment outcome in people with major depressive disorder: an iSPOT-D report. *Translational Psychiatry*, 11(1), 417. <https://doi.org/10.1038/s41398-021-01533-1>