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Original Articles

Can Micronutrients Improve Neurocognitive Functioning in Adults with ADHD and Severe Mood Dysregulation? A Pilot Study

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Abstract

Objectives: Little research has investigated how micronutrients (minerals and vitamins) affect cognitive functioning, despite preliminary studies showing they may improve psychiatric functioning.
Intervention: This pilot study investigated the impact of a 36-ingredient micronutrient formula consisting mainly of vitamins and minerals on neurocognitive functioning in 14 adults with attention-deficit/hyperactivity disorder (ADHD) and severe mood dysregulation.
Design: The formula was consumed in an open-label trial over an 8-week period.
Outcome measures: The participants completed tests of memory (Wide Range Assessment of Memory and Learning) and executive functioning (Delis-Kaplan Executive Functioning System and Conners Continuous Performance Test) at baseline and at the end of the trial. A gender- and age-matched control group of 14 non-ADHD adults not taking the formula were assessed on the same tests 8 weeks apart in order to investigate the impact of practice on the results.
Results: There were no group differences in ethnicity, socio-economic status and estimated IQ. Significant improvement was observed in the ADHD group, but not the control group, across a range of verbal abilities including verbal learning, verbal cognitive flexibility and fluency, and verbal inhibition. These neurocognitive improvements were large and consistent with improved psychiatric functioning. No changes were noted above a practice effect in visual–spatial memory and there were no improvements noted in reaction time, working memory, or rapid naming for either groups.
Conclusions: Although the pilot and open-label design of the study limits the generalizability of the results, it supports a growing body of literature recognizing the importance of nutrients for mental health and cognition. The results also provide evidence supporting the need for randomized clinical trials of micronutrients as well as other experimental studies in order to better assess whether improved neurocognitive functioning may contribute to improved psychiatric symptoms.

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD), characterized by problems with inattention, hyperactivity, and impulsivity, is estimated to occur in 4%–5% of adults.[1] A growing body of literature is emerging on adult ADHD, confirming that many of the difficulties noted in children with ADHD are also present in adults with ADHD. More specifically, impairments have been found across a wide range of neuropsychologic domains in adults with ADHD, including attention, inhibition, visual search, perceptual motor speed, set shifting, verbal fluency, processing speed, and memory.[2–5]

Research has shown that a number of psychiatric medications can improve neuropsychologic functioning of adults with ADHD, although changes are not always consistent. For example, methylphenidate has been found to improve response inhibition,[6] spatial working memory, and sustained attention,[7] and attentional performance, memory, and executive functioning.[8] Atomoxetine has also been found to improve neurocognitive functioning in adults with ADHD as compared with placebo, including improved performance on measures of inhibitory capacity.[9] However, side-effects associated with these medications often make them undesirable for some individuals to consume, and so they resort to

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other therapies that currently have less evidence for their efficacy.

There is a growing body of literature examining the effects of micronutrients and other nutritional supplements on ADHD symptoms (see[10] for a review), and recent studies are showing that by taking a broad approach to the treatment of ADHD and addressing all underlying potential nutritional deficiencies, positive outcomes on psychiatric symptoms can occur. Harding and colleagues[11] compared methylphenidate with a dietary supplement (taurine, glutathione, α-lipoic acid, garlic extract, glycine and other amino acids, 13 minerals, essential fatty acids and phospholipids, iodine and tyrosine, all the B vitamins, and some phytonutrients) in the treatment of ADHD symptoms in 20 children over a 4-week period, and found both groups showed significant and similar improvement in neurocognitive tests. Patel et al.[12] reported an open-label pilot observational study with an even more comprehensive approach. Ten (10) children with both autism and ADHD were treated for 3–6 months with vitamins (A, B-complex), 7 minerals, coenzyme Q10, amino acids and peptides, some essential fatty acids, milk thistle, α-lipoic acid, digestive enzymes, and probiotic bacteria. The researchers reported that, based on parental questionnaires, concentration improved and hyperactivity-related problems decreased.

One micronutrient formula, sold as EMPowerplus, a formula consisting of 36 ingredients (14 vitamins including all the B vitamins, 16 minerals, 3 amino acids, and 3 antioxidants), has been shown to have some positive effects on ADHD symptoms based on two open-label trials with both children and adults.[13,14] Both trials observed participants over a minimum of a 16-week period, reducing the likelihood of the impact of placebo effects on the positive results. A database analysis of 41 children with ADHD who consumed micronutrients over a 6-month period also showed substantial improvement in ADHD symptoms.[15] A case study of a young woman with ADHD and bipolar II disorder showed that improvement in both ADHD and mood symptoms were sustained over 1 year of observation and that consuming the micronutrients also resulted in improved neurocognitive functioning.[16]

A small number of studies have investigated the effects of nutritional supplements on neurocognitive functioning in ADHD samples. Findings have been mixed, with some supplements resulting in improvement and others in no improvement. Sinn and colleagues,[17] in a large double-blind randomized controlled trial ($N = 233$) of polyunsaturated fatty acids (PUFA) supplementation, examined the neurocognitive effects in children with ADHD. It was found that PUFA supplementation significantly improved ability to control and switch attention, compared to placebo. However, no significant improvements were found on measures of general cognitive ability, processing speed, learning and memory, working memory, or distractibility. Furthermore, no significant additional cognitive improvement was found with a multivitamin/mineral supplement over the PUFA supplement alone. Harding and colleagues'[11] study (described above), found that their dietary supplement produced improvements equivalent to methylphenidate in response inhibition, auditory and visual response control, as well as auditory and visual attention. Katz and colleagues,[18] using a double-blind, placebo-controlled, randomized trial with 120 children with ADHD found improved cognitive functioning as assessed by the Test of Variables of Attention, in those children who consumed an herbal treatment (consisting of an herbal mixture and essential vitamins, minerals, fatty acids, and amino acids contained in *Spirulina platensis* [Athrospira]) over a 4-month period. Specifically, the treated group showed improved attention, cognition, and impulse control in comparison to no improvement in the placebo condition. Based on a literature review, the present authors know of no other studies that have investigated the impact of micronutrients on neurocognitive functioning in an ADHD sample.

The present study reports on the neurocognitive outcomes in adults with ADHD and severe mood dysregulation (SMD) when taking a micronutrient formula, EMPowerplus (EMP), data that were collected as part of an intervention pilot trial.[19] This subsample of ADHD (that is with SMD) was chosen for a number of reasons, including the documented effects of EMP on mood,[20] the general consensus in the literature that ADHD with SMD is particularly difficult to treat,[21] and there have been no treatment trials on adults with both ADHD and SMD. Furthermore, SMD is a common symptom of ADHD and recently, researchers are suggesting that SMD may be a core feature of ADHD, with both symptoms resulting in similar deficits in performance on tests of executive function.[22] Other than one case study, the effect of EMP on neurocognitive functioning has not been investigated. As such, this pilot study examined whether a group of adults with ADHD and SMD receiving EMP demonstrated changes across a variety of neurocognitive tests over an 8-week period. A control group of individuals without ADHD who did not receive the formula was recruited for this study in order to assess whether any changes that did occur were above and beyond what would be expected based on practice.

Methods

Participants

The sample consisted of 28 participants (age range 18–63): 14 with ADHD and SMD (9 males, 5 females) and 14 controls (8 males, 6 females). The clinical group had a mean age of 37.5 years (±9.56) and the control group had a mean age of 31.4 years (±14.27). There was no significant difference in the mean ages of the two groups, $t(26) = 1.32$, not significant (*ns*), or in gender between the groups, χ^2 ($N = 28$) $= 0.15$, *ns*. Furthermore, baseline estimated IQ was measured (using the Vocabulary and Block Design subtests of the Wechsler Adult Intelligence Scales[23]) in order to determine whether the two samples were comparable; there was no group difference in estimated IQ scores, $t(26) = 0.18$, *ns*. The mean IQ estimate for the clinical group was 117.8 (17.8), and 116.7 (13.2) for the control group. There was also no group difference in socioeconomic status (using the New Zealand Socioeconomic Index of Occupational Status–96[24]), $t(26) = 1.82$, *ns*, with the mean for both groups falling in the low- to middle-income range.

Participants for the clinical group were recruited through referrals from the public health service, private clinicians and self-referrals, as well as university research files. Participants had to meet criteria for ADHD based on the Conners' Adult ADHD Diagnostic Interview for DSM-IV,[25] a semistructured

interview that assesses for both current and past symptoms of ADHD, and have at least one elevation (T score >65) on one of the DSM-IV subscales of the Conners' Adult ADHD Rating Scales (CAARS[26]) on *either* the self or the observer versions. The Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version (SCID-I[27]) was administered to determine presence of SMD (endorsement of chronic or episodic symptoms of irritable, low or elevated mood either currently or in the past, although not necessarily meeting full criteria for a mood disorder) and to assess for co-occurring disorders, as well as to determine whether another mental disorder could better account for the ADHD symptoms. Six (6) (43%) met criteria for ADHD Predominantly Inattentive Type and 8 (57%) met criteria for ADHD, Combined Type. Other current diagnoses included the following: 10 had a major mood disorder (7 Major Depressive Disorder [50%] and 3 Bipolar Disorder II [21.4%]), 6 Social Phobia (42.9%), 3 Generalized Anxiety Disorder (21.4%), and 3 drug/alcohol abuse (21.4%).

Participants had to be medication free for a minimum of 4 weeks. Participants were *excluded* from the study for any of the following reasons: (1) neurological disorder (e.g., epilepsy, multiple sclerosis, narcolepsy); (2) pregnancy or breastfeeding (pregnancy testing occurred at baseline and monthly thereafter); (3) evidence of untreated or unstable thyroid disease, or abnormality of mineral metabolism (testing occurred at baseline); (4) if they had taken an antibiotic in the previous 6 weeks. If an antibiotic was started during the course of the trial, the patient was withdrawn from the study; (5) evidence of substance dependence within the previous month; and (6) any subject judged clinically to be at current serious risk for suicide, self-harm, or violence. For more information on the clinical sample, refer to Rucklidge, Taylor, and Whitehead,[14] where the data on psychiatric changes and safety of the formula over the 8-week period are presented.

The control group was recruited through local advertising with a focus on trying to match for age and gender of the ADHD group. They were screened and assessed as not having ADHD; however, they did not complete the SCID-I.

Dependent measures

A variety of neurocognitive tests were used to broadly assess cognitive abilities. Alternate forms were used on the second testing session for the Verbal Fluency subtest of the Delis-Kaplan Executive Functioning System (D-KEFS).

Memory. Six subtests from the Wide Range Assessment of Memory and Learning (WRAML-II[28]) were administered to obtain a General Memory Index, a Verbal Memory Index, a Visual Memory Index, and an Attention/Concentration Index. The subtests used were Story Memory, Design Memory, Verbal Learning, Picture Memory, Finger Windows, and Number-Letter.

Executive functioning

Response inhibition (protection from interference)/ distractibility. The Color-Word Test of the D-KEFS[29] was administered to determine a participant's level of distractibility or conversely, their protection from interference. This test yields four dependent measures: color-naming response time, word-reading response times, dissonant ink color–naming response time, and switching between naming the dissonant ink colors and reading the conflicting words response time.

Fluent verbal productivity. The Verbal Fluency subtest of the D-KEFS[29] was administered to determine a participant's ability to generate verbal material according to a specific rule. Verbal Fluency comprises three conditions: letter fluency, category fluency, and category switching. The last condition, category switching, is a means to evaluate the individual's ability to alternate between saying words from two different semantic categories, tapping into the ability to generate words fluently in an effortful, phonemic format while simultaneously shifting between overlearned concepts.

Inhibitory control. The Conners' Continuous Performance Test (CPT-II[30]) was used as a measure of complex cognitive functioning, including attention, visual–motor speed, visual–motor integration, hyperactivity, and impulsivity. The computer generates an output of standardized scores including omissions (believed to be related to inattention), commissions (believed to be a measure of impulsivity), reaction time, and variability of reaction time. A confidence index is also calculated that provides an indication of the likelihood someone has ADHD based on overall performance on the task.

Procedure

Study procedures were approved by both the University and Health and Disability Ethics Committees. As part of this process, participants were well informed of other treatments, including those that have been established as efficacious. Most of the participants had either tried medications and derived little benefit or chose to try a more "natural" treatment first. Participants were not encouraged to stop medications in order to participate in the trial. The baseline neurocognitive assessment was followed by an open-label trial with EMP for the ADHD group for an 8-week period. After 8 weeks, the neurocognitive testing was repeated. Testing was conducted in a laboratory at a university-based psychology department. Neurocognitive tests were administered by a clinical psychologist or graduate student. Pre- and post-testing for each participant were always completed by the same assessor; however, due to the open nature of the trial, they could not be blind to group status.

Results

Paired-sample *t* tests were used to assess for change in the neurocognitive measures in both the ADHD and the control groups. All tests were two tailed, and given that this article represents pilot data, any *p* values less than 0.05 were considered statistically significant. Effect sizes (Cohen's *d*) give an indication of the magnitude of change and were calculated for each outcome variable by dividing the absolute value of the mean of the paired difference by the standard deviation of the difference.

Memory

A significant improvement was observed in Verbal Learning on the WRAML-II in the ADHD sample ($t(13) = 4.77$,

$p < 0.001$, $d = 1.27$). The improvement in Verbal Learning scores was not observed in the control group, suggesting that this improvement is not solely attributed to practice. Although other improvements were noted in memory abilities in the ADHD group (such as in visual memory), these same changes were observed in the control group, suggesting that the memory improvements in these areas were quite likely due to practice effects (Table 1).

Executive functioning

The ADHD group showed a significant improvement in inhibition on the Color-Word Test of the D-KEFS ($t(13) = 3.28$, $p < 0.01$, $d = 0.88$). This change was not observed with the control group, although the control group showed improved performance on the inhibition/switching task (Table 2).

The ADHD group also showed significant improvement on the third condition of the Verbal Fluency subtest, both in correct category responses ($t(13) = 2.43$, $p < 0.05$, $d = 0.65$) and category switching accuracy ($t(13) = 2.42$, $p < .05$, $d = 0.65$). Again, this improvement was not observed in the control group (Table 2).

Finally, on inhibitory control as measured by the CPT-II, the ADHD group showed a significant decrease in number of commissions ($t(13) = -2.91$, $p < 0.05$, $d = 0.78$), although a decrease was also noted in the control group, albeit not as large ($t(13) = -2.40$, $p < 0.05$, $d = 0.64$). Interestingly, although not significant, the ADHD group showed a decrease in the number of omissions, whereas the control group showed an increase in the number of omissions (Table 2).

While correlations were looked at between the variables that changed in the ADHD group and the measures of ADHD and mood symptoms (as reported in Rucklidge et al.[14]), the small sample precluded making any definitive conclusions, because only very large correlations reach statistical significance. Using a liberal p-value of 0.1, only one correlation neared significance: These preliminary analyses suggest that change in inattentive symptoms (as measured by the CAARS self-report DSM inattentive subscale) was most highly correlated with change in verbal learning ($r = 0.44$, $p = 0.1$).

Discussion

In looking at the effect of a micronutrient formula on neurocognitive functioning in adults with ADHD and SMD, the key finding was a consistent improvement in verbal abilities in the ADHD group but not in the control group. More specifically, the ADHD group showed improved verbal memory as assessed by Verbal Learning, improved verbal inhibition as assessed by the Color–Word Test, and improved verbal cognitive flexibility as measured by the Verbal Fluency Test. These improvements are probably not due to practice effects, given that they were not noted in the control group. The changes were medium to large and therefore clinically meaningful. Changes in visual–spatial memory were likely due to practice effects, given that significant changes were observed in both groups. Consistent with negative studies[31] looking at the impact of nutrients on cognition, no improvements were noted in reaction times, rapid naming, and working memory.

Data reported elsewhere on this sample[14] showed significant improvements over the same 8-week time period in terms of improved mood, inattention, hyperactivity, and impulsivity on standardized rating scales, as assessed by clinician, self, and observer reports. Although the improvements noted here may be independent of the improvements in psychiatric symptoms, given that the tests chosen are ones typically impaired in ADHD samples and that show improvement when successfully treated, it is possible that the improved cognitive status has resulted as a consequence of improved psychiatric symptoms. Anecdotal reports from participants indicated that they observed improved word finding abilities, less impulsivity in terms of verbal aggression to others, and fewer interruptions and intrusions on others in social situations.

This is not the first study to observe an improvement across a variety of cognitive tasks after consumption of nutrients. These findings are consistent with more rigorous

Table 1. Memory in the ADHD Group and Control Group at Baseline and Post 8 Weeks Performance

	ADHD sample (n = *14*)					*Control group* (n = *14*)				
Variable	*Baseline Mean (SD)*	*Post 8 weeks Mean (SD)*	t	p	*ES*	*Baseline Mean (± SD)*	*Post 8 weeks Mean (± SD)*	t	p	*ES*
WRAML-II (standard scores)										
Story Memory[a]	11.07 (3.89)	12.36 (3.30)	2.26	< 0.05	0.60	11.00 (2.66)	12.07 (2.37)	2.60	< 0.05	0.69
Design Memory[a]	10.21 (2.64)	11.86 (2.88)	3.45	< 0.01	0.92	9.43 (1.99)	10.71 (1.64)	2.78	< 0.05	0.74
Verbal Learning[b]	9.64 (2.90)	11.64 (3.67)	4.77	< 0.001	1.27	11.29 (2.81)	11.93 (2.89)	1.38	ns	0.37
Picture Memory[a]	9.29 (2.05)	10.21 (2.04)	2.41	< 0.05	0.65	8.36 (2.37)	9.64 (2.13)	2.86	< 0.05	0.76
Finger Windows	10.29 (3.54)	10.36 (2.31)	0.08	ns	0.02	11.14 (3.70)	11.29 (2.37)	0.17	ns	0.05
Number Letter	10.71 (3.15)	11.07 (3.54)	0.75	ns	0.20	11.36 (2.65)	11.64 (3.25)	0.67	ns	0.18
Verbal MI[a]	101.71 (16.32)	111.21 (17.65)	5.10	< 0.001	1.36	106.29 (13.67)	111.21 (13.62)	4.60	< 0.001	1.23
Visual MI[a]	98.43 (10.93)	106.29 (12.42)	4.14	0.001	1.11	93.36 (10.47)	101.07 (9.68)	3.80	< 0.01	1.02
Att/conc Index	102.64 (16.51)	104.21 (13.67)	0.52	ns	0.14	107.00 (14.69)	108.43 (13.80)	0.48	ns	0.13
General MI[a]	100.86 (15.95)	109.36 (15.54)	4.22	0.001	1.13	103.29 (14.24)	109.14 (12.94)	3.39	< 0.01	0.91

[a]Improvements attributable to practice effects.
[b]Indicates significant changes noted in the ADHD group but not in the control group.
ADHD, attention deficit hyperactivity disorder; SD, standard deviation; ES, effect size; WRAML-II, Wide Range Assessment of Memory and Learning; MI, Memory Index; Att/conc Index, Attention and Concentration Index; ns, not significant.

Table 2. Executive Functioning in the ADHD Group and Control Group at Baseline and Post 8 Weeks

	ADHD sample (n=14)					*Control group (n=14)*				
Variable	*Baseline Mean (SD)*	*Post 8 weeks Mean (SD)*	t	p	*ES*	*Baseline Mean (SD)*	*Post 8 weeks Mean (SD)*	t	p	*ES*
D-KEFS (standard scores)										
Color-Word										
Color	9.14 (2.32)	9.29 (2.81)	0.22	ns	0.06	11.36 (2.24)	11.50 (1.65)	0.46	ns	0.12
Word	8.93 (3.45)	10.00 (3.37)	1.99	ns	0.53	11.64 (2.02)	11.64 (1.95)	0	ns	0
Inhibition[a]	8.93 (3.81)	11.07 (2.56)	3.28	<0.01	0.88	11.79 (2.29)	12.36 (2.27)	1.67	ns	0.45
Inhibition/switching	10.29 (3.20)	10.50 (3.03)	0.59	ns	0.16	11.50 (2.50)	12.43 (2.10)	3.24	<0.01	0.87
Verbal fluency										
Letter fluency	11.14 (3.53)	11.71 (3.50)	0.98	ns	0.26	12.21 (3.64)	12.79 (1.85)	0.91	ns	0.24
Category fluency	12.93 (4.12)	11.57 (3.59)	−1.86	ns	−0.50	13.36 (3.30)	12.14 (2.25)	−1.64	ns	−0.44
Switching correct[a]	11.36 (3.15)	13.64 (3.30)	2.43	<0.05	0.65	12.69 (2.18)	12.85 (2.58)	0.17	ns	0.05
Switching accuracy[a]	11.93 (2.53)	14.00 (2.75)	2.42	<0.05	0.65	12.69 (2.18)	12.92 (2.06)	0.35	ns	0.15
CPT-II (T-scores)										
Omissions	52.27 (22.03)	50.07 (17.51)	−0.95	ns	−0.25	49.02 (9.18)	51.55 (10.24)	1.40	ns	0.38
Commissions[b]	53.12 (9.22)	47.20 (8.69)	−2.91	<0.05	−0.78	51.01 (10.53)	46.22 (10.85)	−2.40	<0.05	−0.64
Reaction Time	48.19 (9.68)	49.33 (9.91)	0.52	ns	0.14	45.83 (11.42)	45.34 (10.82)	−0.31	ns	−0.08
Variability	54.91 (7.26)	53.20 (11.86)	−0.54	ns	−0.14	46.57 (8.42)	44.00 (11.44)	−1.00	ns	−0.27
Confidence Index	54.39 (22.86)	54.74 (22.67)	0.10	ns	0.03	41.52 (26.47)	41.86 (25.26)	0.08	ns	0.02

[a]Indicates significant changes noted in the ADHD sample but not in the control group.
[b]Indicates improvements attributable to practice effects.
ADHD, attention deficit hyperactivity disorder; SD, standard deviation; ES, effect size; D-KEFS, Delis-Kaplan Executive Functioning System; CPT-II, Continuous Performance Task; ns, not significant.

controlled trials showing that micronutrients can improve cognitive functioning across not only ADHD[18] but also other disorders. For example, Schoenthaler et al.,[32] using a placebo-controlled randomized trial, documented that children's intelligence improved when taking micronutrients. A vitamin/nutriceutical formulation was shown to reduce cognitive decline in later-stage Alzheimer's disease,[33] also based on a placebo-controlled trial. At this point, it is speculative as to why nutrients might improve brain function; theories to date include the following: nutrients optimize the manufacture of neurotransmitters,[34] they may increase dopamine availability,[35] they correct deficiencies present in Western diets,[36] improve the production of adenosine triphosphate,[37] or may correct inborn errors of metabolism that slow metabolic reactions.[38]

Verbal memory and fluency are cognitive abilities known to be deficient in both ADHD and mood-dysregulated samples and can improve with treatment.[3,39] Given that this sample consisted of individuals with both ADHD and mood difficulties and both ADHD and mood symptoms were noted to improve,[14] it cannot be determined whether improvement in one of these areas or a combination resulted in this improved verbal functioning in the clinical sample in this study. Skirrow et al.[22] have proposed that ADHD and SMD may arise from the same causal processes that also impair cognitive functioning, so the mechanisms that led to improved psychiatric symptoms may also have improved some aspects of cognitive functioning. While a potential problem with the design (which also limits generalizability to the broader ADHD population), it could also be viewed as a strength in that this sample was more representative of clinical samples as a whole, given that there was a large range of co-occurring disorders including mood, anxiety, and substance abuse. Typically, such a sample is more difficult to treat. Therefore, not only did their psychiatric status and certain aspects of their neurocognitive functioning improve over an 8-week period, but also the micronutrient formula did not result in a decline in cognitive functioning, providing further evidence of its safety. A larger sample is required in order to conduct regressions to determine whether changes in specific symptoms are driving these specific neurocognitive improvements. It is also possible that those verbal abilities improved regardless of psychiatric improvement and that these changes may occur within a healthy group as well.

These pilot data are limited by the small sample size, which limited the number of analyses that could be performed as well as reduced the power to detect more subtle cognitive changes. The small sample precluded more in-depth analyses such as looking at ADHD subtype differences or the effect of co-occurring disorders on the results. However, the fact that some significant changes were observed with such a small sample size does suggest that the effect of micronutrients on cognitive functioning could be a substantial one. Ideally, it would be important to explore which changes in psychiatric symptoms could best explain the observed cognitive improvements. If the groups had been comparable on psychiatric status, repeated analyses of variance could have been performed to directly compare the two groups. However, given the fact that there were so many differences at baseline in neurocognitive functioning (despite similar estimated IQ), such comparisons could not be conducted with such a small sample size. Although a comparison to a group of individuals with ADHD who did not receive the micronutrient formula would have been a better-matched group, ethical issues prevented such a sample from being used. However, the control group used here should have been a more rigorous comparison group, given that the greater cognitive deficits present in the ADHD group may

result in less susceptibility to practice effects as compared with those without ADHD symptoms.

Other limitations include the high IQ of the ADHD sample, thus limiting generalizability to all individuals affected with ADHD. The open-label design could have resulted in trial participants trying harder the second time around as compared with the controls and in turn, subtly influencing those conducting the neurocognitive testing. This may have also subtly influenced the testers. It also cannot be determined whether the changes noted in the ADHD group were not due to some other change occurring simultaneously to the supplementation, such as improved diet, improved sleep, or some other intervention. There certainly is evidence showing that improved diet affects neuropsychological function.[40] The sample group was not taking other medications or supplements during the trial, and while a couple of them did see a counselor for a few sessions during the trial, the impact of such contact is probably negligible.

Conclusions

While many limitations exist, this is the first study that has investigated the effect of micronutrients on neurocognitive functioning in a sample of adults with ADHD and SMD. Although the findings are preliminary, the neurocognitive improvements that were identified are consistent with observed changes in psychiatric symptoms but are less influenced by observer and clinician biases inherent in an open-label trial. Given that many individuals with ADHD do not want to take conventional medications for their symptoms, it is important that other treatments be empirically tested; a randomized control trial is currently under way. If substantiated with better-controlled trials, this treatment approach could potentially offer a viable, safe alternative for the treatment of complex presentations of ADHD and its associated neurocognitive impairments.

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