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Hyperactive Child Syndrome and Estimated Life Expectancy at Young Adult Follow-Up: The Role of ADHD Persistence and Other Potential Predictors

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Abstract

Objective: We examined if ADHD Combined Type or Presentation (ADHD-C) reduced estimated life expectancy (ELE) at young adulthood and if the persistence of ADHD to adulthood further adversely affected ELE. **Method:** A young adult follow-up of 131 hyperactive and 71 control cases was used to derive 14 variables that were entered into a life expectancy calculator to generate ELE scores. Both ratings of executive function (EF) in everyday life and tests of EF and IQ were measured along with comorbid psychopathologies. **Results:** Childhood ADHD-C was associated with a 9.5-year reduction in healthy ELE, and a 8.4-year reduction in total ELE relative to control children by adulthood. The persistence of ADHD to adulthood was linked to a 12.7-year reduction in ELE. Several background traits accounted for more than 39% of variation in ELE. **Conclusion:** Childhood ADHD-C predicts a significantly reduced ELE by adulthood, which is further reduced by the persistence of ADHD to adult follow-up. *(J. of Att. Dis. XXXX; XX*[*X*] *XX-XX)*

Keywords

ADHD, estimated life expectancy, young adult follow-up, behavioral inhibition

ADHD is a neurodevelopmental disorder (American Psychiatric Association [APA], 2013) affecting 5% to 10% of children and 3% to 5% of adults (Willcutt, 2012). The disorder persists into adulthood in approximately 40% to 65% of cases diagnosed in childhood (Faraone et al., 2015; Owens, Cardoos, & Hinshaw, 2015). The condition was previously known as hyperkinetic reaction of childhood or hyperactive child syndrome (Barkley, 2015c). Despite the focus on motor activity in the term, descriptions of the syndrome also emphasized the importance of symptoms of inattention and impulsivity (APA, 1968; Cantwell, 1975) just as do current descriptions of ADHD Combined Type or Presentation (ADHD-C; APA, 2013).

Estimated life expectancy (ELE) refers to the number of years of life remaining at a specific age and is based on actuarial life tables of large population samples, such as those provided by the U.S. Social Security Administration (SSA). ELE can then be further adjusted by disability conditions and health-related variables based on their demonstrated impact on life expectancy in population samples apart from age and sex effects. These adjustments are known as Disability Adjusted Life Years (DALY) and Health Adjusted Life Years (HALY) calculations of ELE. There are at least five empirical reasons to hypothesize that hyperactive child syndrome, or ADHD-C, would be associated with a reduction in ELE so adjusted by adulthood:

1. Some longitudinal studies of hyperactive child syndrome, or those diagnosed with ADHD, are beginning to document increased death rates by young adult follow-up even if not yet significantly different from control groups (Barbaresi et al., 2013). However, others have not yet shown such differences by young adulthood (Barkley, Murphy, & Fischer, 2008). This lack of significance could be related to inadequate lengths of follow-up periods to detect differential death rates. As evidence of such, the longest running follow-up study that has followed their participants to midlife has reported a small but significant group difference (7.2% vs. 2.8%, respectively) by a mean age of 41 years (Klein et al., 2012).
2. ADHD is linked to increased adverse consequences in nearly every major domain of life activity studied to date (Barkley et al., 2008), some of which are

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linked to shortened life expectancy. For instance, ADHD is associated with higher risks for accidental and self-inflicted injuries in childhood and adulthood (Nigg, 2013) and that lead to increased emergency room admissions (Cuffe, Moore, & McKeown, 2009). Adverse driving outcomes, including more vehicular crashes (Barkley, 2015b; Barkley & Cox, 2007), are also associated with ADHD. ADHD is also associated with an increased risk for suicidal ideation, attempts, and completions (Barbaresi et al., 2013; Barkley et al., 2008). While comorbid depression in such cases is the major predictor of the greater risk for suicidal ideation, it is the impulsivity linked to ADHD-C that accounts for its greater risk for suicide attempts and completions (Barkley et al., 2008). All of these adverse outcomes intimate a likely reduction in ELE being associated with ADHD-C by adulthood.

3. ADHD is associated with various adverse medical conditions, including increased rates of seizures, obesity, eating pathology, traumatic brain injury, tobacco, alcohol, and marijuana use; dental trauma and caries; sedentary behavior or low rates of exercise;, sleeping problems, migraines, and risk for future coronary heart disease, as well as decreased involvement in preventive health, nutrition, and dental hygiene activities (Barkley, 2015a; Barkley et al., 2008; Nigg, 2013). Many of these conditions, well-known correlates of reduced ELE, are used in making DALY and HALY adjustments in calculations of ELE. They are also the focus of various societal efforts at their improvement by public health authorities in efforts to improve quality of life generally and life span specifically.
4. Teens and adults with ADHD-C are far more likely to be involved in interpersonal hostility generally and antisocial activities specifically that include violent crimes, reactive aggression, and intimate partner violence even when conduct disorder is not present or is statistically controlled (Buitelaar, Posthumus, & Buitelaar, 2015; Mohr-Jensen & Steinhausen, 2016; Saylor & Amann, 2016). All of these variables would predispose to an increased risk for greater morbidity and likely earlier mortality by violent means.
5. A few recent studies have specifically examined the issue of greater mortality in ADHD, using large epidemiological samples or even entire populations. In most cases, they show that in childhood the mortality risk is nearly doubled that of the typical comparable population, and in adulthood, that risk is more than quadrupled (Dalsgaard, Ostergaard, Leckman, Mortensen, & Pedersen, 2015; Jokela, Ferrie, & Kivimaki, 2009; London & Landes, 2016). This risk of earlier mortality seems to be largely a result of not only a greater proneness to accidental injury but also, to a lesser extent, from an elevated risk for suicide (Barbaresi et al., 2013; Dalsgaard et al., 2015). However, a much smaller study of 1,489 adults with ADHD enrolled in drug trials did not find significantly elevated mortality during the period of the drug evaluations (Khan, Faucett, Morrison, & Brown, 2013). But these results could be due to the smaller samples, shorter duration of the ascertainment window, and screening of study participants for health risks that might preclude study participation thus ruling out the least healthy ADHD adults.

Yet, greater mortality risk ratios in ADHD do not provide a direct estimate of reduced remaining years of life expectancy across adulthood. That is because very early mortality in childhood or young adulthood, such as related to accidental injuries, which has been documented in such cross-sectional studies is not reflective of later longevity risks that may arise from lifestyle factors used in DALY and HALY adjustments to ELE. The impact of those disability and health factors may produce cumulative health risks when chronic, such as excessive smoking, use of alcohol, drug abuse, poor diet, poor sleep, and limited exercise, among other health and lifestyle factors. Such factors caneventually lead to earlier death in mid-to-late life. Thus, it is still valuable to examine the ELE in young adults with ADHD-C that is associated with such health and lifestyle factors apart from what is already known about elevated mortality risk earlier in life in ADHD-C. For all of these reasons, we hypothesized that hyperactive child syndrome (ADHD-C), particularly if it was associated with the persistence of ADHD to adulthood, would be linked to a significant reduction in both total ELE and healthy ELE as well as an increase in unhealthy ELE by young adulthood.

The foregoing health and lifestyle factors that may affect ELE may be thought of as proximal or first order variables that are directly employed in algorithms to predict ELE, as often occurs in epidemiological research concerning public health within and across populations, countries, and ethnic groups. However, no research in ADHD-C has employed health and lifestyle factors for estimating ELE using DALY/HALY calculator algorithms. We propose to do so here.

Research has shown, however, that many of these first order health and lifestyle factors may be partially a function of second order background or more distal variables such as traits inherent in the individual that predispose them more than others to engaging in such health-adverse activities. Those background traits could be related to personality, cognitive deficits, psychopathologies, and even genetics. For instance, twin research has found that while smoking conveys an increased risk of mortality in identical twins discordant for smoking, thus supporting its direct contribution to reduced ELE, this is not the case for low physical activity or high alcohol use. In those cases, there was no difference in mortality risk despite discordance for these activities (Kujala, Kaprio, & Koskenvuo, 2002). This implies that it is the genetic predisposition for such mortality risk that may underlie reduced ELE associated with low physical activity and heavy alcohol use rather than a direct effect of these adverse health activities.

One personality trait that has been strongly and consistently predictive of ELE and actual longevity and may underlie predispositions to engage in the above lifestyle risk factors is that of Conscientiousness (Bogg & Roberts, 2004; Hampson, 2008). This trait refers to the degree to which one relies on his or her conscience specifically and self-regulation and contemplation more generally to engage in decisions and actions that benefit one's longer term welfare over one's immediate gratification. For instance, low Conscientiousness in childhood (defined as the bottom quartile) is associated with reduced longevity by 7 to 8 years even among gifted individuals followed across their life spans (Friedman et al., 1995). Low Conscientiousness also predicts an increased risk for death by all causes (Bogg & Roberts, 2004; Hampson, 2008). Moreover, risk for coronary heart disease and cardiac arrest increase by 20% for each decrease of 1 *SD* in self-regulation (Kubzansky, Park, Peterson, Vokonas, & Sparrow, 2011) and, by inference, in Conscientiousness. Conscientiousness is negatively correlated with poor self-regulation generally and impulsivity or behavioral disinhibition specifically (Sharma, Markon, & Clark, 2014; Whiteside & Lynam, 2001). As might be expected from this negative association, Conscientiousness is also negatively associated with ADHD symptoms, which include behavioral disinhibition (Brainstorm Consortium, 2018; Martel, Nikolas, Jernigan, Fridericic, & Nigg, 2010). This association of Conscientiousness with ADHD may be due in part to their shared heritability (Brainstorm Consortium, 2018). Thus, it may be through its behavioral disinhibition component (and hence low Conscientiousness) that ADHD-C predisposes to those adverse health and lifestyle factors that reduce ELE.

This argument also provides a theoretical basis to logically hypothesize reduced ELE in ADHD-C. Behavioral inhibition is considered to be one of the seven major executive functions (EFs), along with sustained attention, working memory (both verbal and nonverbal), planning and problem solving, emotional self-regulation, and self-motivation (Barkley, 2012a). One major theory of ADHD-C is that it involves substantial deficits or delays in these EF components and especially inhibition and working memory (Barkley, 1997, 2015d), as has been abundantly evident in research on ADHD and EF (Frazier, Demareem, & Youngstrom, 2004; Hervey, Epstein, & Curry, 2004; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Besides these cognitive EFs, individuals also engage in actions in daily life that comprise the five major EFs evident in those daily life activities, such as self-restraint, time management, self-organization and problem solving, emotional self-regulation, and self-motivation (Barkley, 2012a, 2012b). Cognitive tests and rating scales for assessing EF are, surprisingly, not significantly correlated (Toplak, West, & Stanovich, 2013). Individuals with ADHD-C are substantially and pervasively deficient in such everyday EFs in both childhood (Gioia, Isquith, Kenworthy, & Barton, 2002) and adulthood (Barkley & Fischer, 2011; Barkley & Murphy, 2011), with deficient behavioral inhibition being especially prominent (Barkley & Murphy, 2011; Gioia et al., 2002; Thorell, Eninger, Brocki, & Bohlin, 2010). Hence, this theory of ADHD-C as involving deficient EF might also provide another trait or set of traits inherent in the individual that partially explains the proclivity of those with ADHD to engage in more adverse health and lifestyle activities that lead to reduced ELE.

A third inherent trait that could indirectly influence longevity through its impact on health and lifestyle practices is intelligence, another cognitive trait that overlaps to some extent with EF. Reviews of the literature clearly support a role of lower intelligence in the first two decades of life as being associated with increased risk for later mortality, even controlling for confounding factors in early life (Batty, Deaery, & Gottfredson, 2007). This effect may be partially mediated through the effects of IQ on education, occupational income, and other more proximal factors used in estimating life expectancy. ADHD is known to have a small but reliable, meaningful, and inherent negative association with intelligence with which it shares 6% to 12% of its variance (Tillman, Bohlin, Sorenson, & Lundervold, 2009). This relationship is through shared genetic and developmental etiological influences (Mill, Caspi, Williams, Craig, Taylor et al., 2006; Rommel, Rijsdijk, Greven, Asherson, & Kuntsi, 2015) and to some extent (4% to 46%) may be mediated by EF components related to both variables (Tillman et al., 2009). Hence, there is good reason to examine IQ in addition to EF deficits and behavioral disinhibition (low Conscientiousness) as second order traits related to ADHD that are also related to reduced ELE.

To test our hypothesis of reduced ELE in ADHD-C, the present study used health and lifestyle information from a longitudinal study of children diagnosed with Hyperactive Child Syndrome (ADHD-C) followed to young adulthood to estimate remaining ELE by ages 24 to 32 (mean age 27 years) relative to a concurrently followed community control (CC) group of children (Barkley et al., 2008). To test our second hypothesis that persistence of ADHD to adulthood would produce an even greater deleterious effect on ELE, we rediagnosed participants at their young adult outcome as to presence or absence of ADHD using modified *Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition (*DSM-IV*; APA, 1994) criteria.

Several additional specific aims were also addressed here. One was to evaluate which first order health and lifestyle factors used to calculate ELE in a DALY/HALY calculator may underlie any reduction found to be associated with ADHD-C. A further aim was to evaluate several second order or background traits inherent in individuals that might be contributing to variation in ELE, given that they predispose to adverse health and lifestyle factors and so to ELE. We therefore evaluated the second order traits of IQ and EF, including behavioral disinhibition. We evaluated EF using both neuropsychological testing and ratings of EF in daily life, given that the information provided by these different methods of evaluating EF have no significant relationship to each other (Toplak et al., 2013). Although we had no direct measure of Conscientiousness in this project, our EF measures of behavioral disinhibition, particularly EF ratings in daily life, could serve as a proxy for low Conscientiousness here given their strong negative relationship. An additional background or second order trait that might predispose to adverse health and lifestyle factors, and hence to reduced ELE in studies of ADHD, is its common comorbid psychopathologies (such as hostility, anxiety, and depression; Nordentoft et al., 2013). Therefore, a further aim of this study was to evaluate any contribution being made to ELE by such psychopathologies apart from those made by the other background trait factors.

Method

Participants

Samples. This study utilized 158 children determined as having hyperactive (H) child syndrome (the diagnostic term for ADHD-C at the time) and a matched CC group ($N = 81$) followed concurrently. The groups were originally evaluated in 1979 to 1980 when they were aged 4 to 12 years (Barkley, Karlsson, Strzelecki, & Murphy, 1984). Most (Hyperactive $n = 123$, or 78%; Normal $n = 66$, or 81%) were evaluated again as teens in 1987 to 1988 when they were 12 to 20 years of age (mean age of 14 years; Barkley, Fischer, Edelbrock, & Smallish, 1990). The participants were reassessed at early adulthood in 1992 to 1996 at 19 to 25 years of age (mean age of 20 years; Barkley, Fischer, Smallish, & Fletcher, 2002). The final follow-up serving as the basis for this article was in adulthood ages 24 to 32 (mean age of 27 years) conducted from 1998 to 2004 (Barkley et al., 2008). A total of 131 of the original H participants agreed to participate in all aspects of the study including the physical exam (83%). Seventy-one of the original 81 CC participants (88%) did so as well. Results from this final young adult follow-up appear elsewhere (Barkley & Fischer, 2011; Barkley et al., 2008).

Recruitment at childhood entry. At childhood entry, all participants were required to (a) have a verbal IQ greater than 80 on the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981), (b) be free of gross sensory or motor abnormalities, and (c) be the biological offspring of their current mothers or have been adopted by them shortly after birth. The original gender composition was 91% male and 9% female; a typical Male: Female ratio for clinic-referred children having ADHD at the time. The racial composition at entry was 94% White, 5% Black, and 1% Hispanic.

The H group was originally recruited from consecutive referrals to a child neuropsychology service in the Midwest that also specialized in the treatment of H children. The CC children were recruited using a "snowball" technique in which the parents of the H children were asked to provide the names of their friends who had children within the age range of interest to the study. These friends of the parents then were contacted about the study. Those eligible were seen for the initial evaluation. At that time, they were asked about other friends of theirs who had children. These families were contacted to participate and so on. As such, this CC group is not a random or necessarily representative sample of the regional population but was intended to try and more closely equate hyperactive and control cases on demographic and socioeconomic factors.

For this young adult follow-up, all participants were contacted by phone, given an explanation of the study, and urged to volunteer to be reevaluated. They were then scheduled for their evaluations over a 2-day period at which time formal written consent was obtained. The battery of measures assessed psychiatric disorders, history of mental health treatments, outcomes in major life activities (education, occupation, dating, sexual activity, driving, money management, etc.), antisocial activities and drug use, and medical history. Some psychological tests and rating scales were also collected. The measures and results are described in detail in other sources (Barkley et al., 2008). Participants were asked to provide the name of another adult who could best describe their current functioning and to give permission for project staff to contact and interview this person about them. These interviews were conducted by an experienced master's-level psychological assistant and supervised by a licensed board-certified doctoral neuropsychologist. This assistant was not blind to original group membership at study entry. However, she was blind to the subgroup designation of having persistent disorder or not. The longitudinal study was reviewed and approved by the medical university institutional review board at each of the follow-up points, and all participants signed statements of informed consent, as did collaterals providing information about the participants. Participants and those collateral sources were paid for their time.

Participant selection criteria at childhood entry. Official diagnostic criteria for ADHD were not available at the time these children were recruited other than the one sentence describing hyperkinetic reaction of childhood in the *DSM*, Second Edition (DSM-II; APA, 1968). Developmentally referenced research criteria that existed at the time were therefore used for identifying H children at study entry (Barkley, 1982). To be considered for the H group, the children had to (a) have scores on both the hyperactivity index of the Revised Conners' Parent Rating Scale–Revised (CPRS-R; Goyette, Conners, & Ulrich, 1978) and the Werry-Weiss-Peters Activity Rating Scale (WWPARS; Barkley, 1981) that met or exceeded 2 *SD*s above the mean for severity for same age, same sex normal children [the former scale contained items reflecting inattention, impulsivity, and hyperactivity, while the latter scale comprised items mainly reflecting hyperactive behavior in various situations]; (b) have scores on the Home Situations Questionnaire (Barkley, 1990) indicating pervasive behavioral problems in at least six or more of the 14 problem situations on this scale (a score exceeding +1 *SD*); (c) have parent and/or teacher complaints (as reported in a parent interview) of poor sustained attention, poor impulse control, and excessive activity level; (d) have developed their behavior problems prior to 6 years of age; (e) have had their behavioral problems for at least 12 months; and (f) have no indication of autism, psychosis, thought disorder, epilepsy, gross brain damage, or mental retardation. Such criteria are as or more strict than those for ADHD in *DSM-IV* (APA, 1994) available at the young adult follow-up.

In view of the selection criteria used here and the close convergence of rating scale diagnoses with the clinical diagnosis of ADHD (Edelbrock & Costello, 1988), it is likely that all participants would have met criteria for ADHD based on the *DSM-IV* had those been available. In fact, over 70% of them met the highly similar *DSM*, Third Edition, Revised (*DSM-III-R*; APA, 1987) criteria for ADHD 8 to 10 years later at the adolescent follow-up (Barkley et al., 1990).

Eligibility for the CC group was based on (a) no history of referral to a mental health professional, (b) no current parental or teacher complaints of significant behavioral problems, (c) scores within 1.5 *SD*s of the typical mean on both the hyperactivity index of the CPRS-R and the WWPARS, and (d) no evidence of any other psychiatric disorder.

Determining the presence of ADHD in adulthood. A structured interview involving *DSM-IV* criteria for ADHD (APA, 1994) was created and employed at follow-up, given that no structured interview using precisely these criteria then existed for use with adults to evaluate the presence of this disorder. Symptoms of ADHD were reviewed twice, once for current functioning (past 6 months) and a second time for childhood between 5 and 12 years of age, with the requirement that the symptom only be endorsed if it occurred often or more frequently. A symptom count was calculated from each symptom list. The age of onset of symptoms was also determined. Six domains of impairment (functional ineffectiveness) were also reviewed with impairment having to occur often or more frequently and at what age each domain became impaired. The domains were occupational, home, social, community activities, education, and dating/marriage. The interview has been used successfully in other studies of adult ADHD (Barkley et al., 2008).

One could simply apply the *DSM-IV* criteria as written to these adults to identify presence of ADHD in adulthood. If that were done, then 30% of the H group would meet the *DSM-IV* threshold of having at least six of nine symptoms on either symptom list by self-report. Adding the additional criterion of having impairment in at least one or more domains by self-report reduces this figure to 24%. The results for the control group would be 3% using symptoms only and 1% using symptoms and impairment. If the reports of others (the collaterals) are used instead to define ADHD, these figures would be 26% for having six of nine symptoms and 25% for having those symptoms plus impairment for the H group (1% for controls in either case).

Yet there are good reasons to challenge this approach to diagnosing adults with ADHD, especially in follow-up studies of children with ADHD (Barkley et al., 2008; McGough & Barkley, 2004). The *DSM* items and thresholds were designed for use with children, not adults. Given that ADHD symptoms decline significantly with age in both ADHD and typical populations (Owens et al., 2015), symptom thresholds used with children may not be equally applicable for identifying adults with ADHD as they would represent an increasing severity level with age. Previous research (Barkley, 2011) suggests that a threshold of four self-reported symptoms on either list is sufficient to accurately classify ADHD in adults, and represents the 93rd percentile or +1.5 *SD*s above the general population mean. Applying this threshold along with a requirement for impairment resulted in 44% (n = 55) meeting these developmental criteria. Henceforth, this group is called ADHD present (or H + ADHD, for H children and currently ADHD in young adulthood). The remaining 80 members of the H group who did not meet these criteria are referred to as ADHD nonpresent (or H – ADHD).

Demographic information. The groups did not differ in their sex composition (84% to 93% males). There were just nine females in the H + ADHD group, 11 in the H – ADHD group, and five in the control group, precluding the examination of potential sex differences having satisfactory statistical power. A slightly yet significantly lower percentage of the two hyperactive groups consisted of self-identified White or European American ethnic identity (81% to 84% White) at follow-up in comparison with the control group (97% White). Groups did not differ in the proportions that were currently single, married, or separated/divorced, with approximately 30% to 43% of our groups being currently

Table 1. Demographic Characteristics by Group for Dimensional Measures.

Group:	(1) H + ADHD		(2) H – ADHD		(3) Community				Pair-wise
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Contrasts
Age (years)	26.8	1.4	27.2	1.4	26.9	0.8	1.52	*ns*	
Education (years)	12.2	2.2	12.8	2.1	15.8	2.3	51.49	<.001	1,2 < 3
Verbal IQ (WAIS-III vocabulary)	10.5	3.4	10.6	3.3	14.1	2.6	29.55	<.001	1,2 < 3
Nonverbal IQ (WAIS-III block design)	11.6	3.2	11.6	3.4	13.0	2.9	4.85	.009	1,2 < 3
Hollingshead job index	32.3	19.8	40.1	20.6	56.0	27.0	18.11	<.001	1,2 < 3
Hollingshead SES	28.4	11.2	33.2	12.7	45.4	15.1	28.80	<.001	1,2 < 3

Note. H + ADHD = hyperactive group that currently has a diagnosis of ADHD at follow-up. H – ADHD = hyperactive group that does not have a diagnosis of ADHD at follow-up; *ns* = not significant; WAIS-III = Wechlser Adult Intelligence Test–Third Edition; SES = socioeconomic status.

married. Significantly fewer H + ADHD cases were currently employed compared with the H – ADHD and CC groups. The dimensional demographic features are displayed in Table 1. The ages of the groups are comparable (age 27 years). Both of the H groups had less education, lower Hollingshead job index scores, and lower IQ estimates than the CC group consistent with other longitudinal studies of ADHD children.

Treatment history. The vast majority of individuals in the two H groups were not currently receiving any form of treatment nor were they at the last follow-up. That fact likely accounts for why no effects of earlier treatment were evident in any domain of functioning evaluated in this project by young adulthood, either at age-21 or age-27 follow-ups (Barkley et al., 2008). Thus, treatment history was not examined here for any relationship to ELE.

Dependent Measures

ELE Calculator and Output Scores

It is common practice now in public health research to employ disability and health factor adjustments to estimate remaining life expectancy, or ELE (in years of life remaining), such as is done by the World Health Organization[1] in their research comparisons across member countries and by the Centers for Disease Control and Prevention.[2] Large databases on populations are used to calculate initial mortality rates and these rates are then adjusted for various health and lifestyle factors shown to have an impact on life expectancy in those populations. Formulas then combine weightings of such factors[3] to produce an estimate of total, unhealthy, and, more recently, healthy years of life remaining (Crimmins & Saito, 2001; Mathers, Sadana, Salomon, Murray, & Lopez, 2001; Murray et al., 2015; Robine & Ritchie, 1991). Of the various ELE calculators that are available on the Internet and thus are publicly available, we used one (a) not commercially affiliated; (b) of relatively recent origin to insure that the actuarial databases used to construct it and its regression weights were founded on current population samples and their mortality tables; (c) founded on large actuarial databases known as life tables similar to those used in epidemiological research on ELE and in the insurance industry; (d) that used a sufficient number of relevant variables to adjust the calculation of the ELE values for each individual beyond what would merely be available through government actuarial tables based on age, sex, and race; and (e) that contained variables that were collected in our follow-up study or could be extrapolated from them. The ELE calculator at the Goldenson Center for Actuarial Research, University of Connecticut (UCONN) met these requirements (see https://apps.goldensoncenter.uconn.edu/HLEC/).

This ELE Calculator is based on a model employing three input assumptions: (a) for healthy mortality, it used the first year Society of Actuaries select life mortality rates; (b) for the incidence rate of disability, it used the Society of Actuaries annuitant disabled rates; and (c) for the mortality rates of disabled lives, it employed the Social Security disabled mortality rates. The developer then used a multiple-decrement actuarial modeling algorithm to calculate healthy life expectancy (HLE; years left free of disability and ill-health; Jagger & Robine, 2011; Robine & Ritchie, 1991), unhealthy life expectancy (ULE; years left with disability and ill-health, also known as DALY; Murray et al., 2015; Robine & Ritchie, 1991), and total life expectancy (LE = HLE + ULE). The three input assumptions were adjusted for 14 individual health and lifestyle variables (such as education, body mass index [BMI], diet, exercise, sleep, etc.) using a factor approach based on quintiles of the HLE distribution.

The ELE Calculator requires the entry of 14 variables. These are set forth in Table 2 along with the source used from the study database to derive each variable and any adjustments that were required to adapt the information into that format required by the Calculator. Unique to this calculator is its estimation of both healthy and unhealthy years of life remaining rather than just total ELE. It also provides an estimate of the percent difference between the individual

Table 2. Variables Used in the ELE Calculator to Compute Estimated Life Expectancies.

Variable	Units	Source	Adjustments (if any)
Gender	Male/female	Interview	
Age	Years	Interview	
Weight	Pounds	Phys. exam	
Height	Feet and inches	Phys. exam	
Education	Less than HS, HS, college, graduate	Interview	All cases were entered as HS except for those having less education. Then 11 months was added to the HLE and LE output for each additional year of education after high school based on more recent research supporting this adjustment(Joshi et al., 2017)
Income	<US$25K, US$25K-US$50K, US$50K-US$75K, US$75K-US$100K, US$100K+	Interview	
Exercise	Never, rarely, 1-2 days/week, 3-4 days/week, 5+ days/week	Interview	
Current health	Poor, fair, good, very good, excellent	Interview	Based on responses to 59 possible current medical health complaints answered as currently a problem or not as described elsewhere(Barkley et al., 2008). The total number of such complaints was computed. Then the distribution of such scores for the CC group was used to create the five quintile ranges (0-20 percentile, 21-40 percentile, etc.). These ranges then served to determine the category entered for this variable with the highest quintile corresponding to Poor, next highest to Fair, and so on.
Type 2 diabetes	No/yes	Interview	
Diet	Poor, fair, good, very good, excellent	SCLI	This interview (Skinner, 1994) evaluates 16 domains of self-reported lifestyle, one of which is the Nutrition domain score. Scores reflect placement within one of three ranges corresponding to a Risk or Concern, or a Strength. We coded the Risk and Concern output as Poor and the Strength output as Good, thus using only two of the five possible entries.
Sleep	<5 hr, 5-8 hr, or 8+ hr per night	SCLI	Information on the Sleep domain is among the 16 domains assessed in this interview. Output from this assessment coded as a Risk or Concern was entered as the <5 hr category while output coded as a Strength was entered as 8+ hr.
Smoking	Nonsmoker, smoker	Interview	We also had data on how many cigarettes per day the individual reported currently smoking. Recent research shows (Joshi et al., 2017) that ELE can be adjusted further beyond that done in this calculator by determining if an individual also smokes 20 or more cigarettes per day. That study indicates that smoking that amount or more per day reduces LE by 6.4 years. The ELE Calculator already reduces its output by 4 years if someone is a smoker. So the outputs of the calculator for HLE and LE were further adjusted downward by another 2.4 years for any participant also reporting smoking 20+ cigarettes per day.
Driving	0, 1, or 2+	Interview	This is intended as a self-assessment reflecting risky driving. It is usually entered as one of three categories: 0 accidents per year (of driving), 1 accident a year, and 2+ accidents a year. However, as discussed with the ELE Calculator developer, this is a markedly unrealistic index of risky driving as no one in our study had 1 or more accidents per year in their driving career that spanned 10 to 19 years. Given that teens and adults with ADHD are among the riskiest and accident prone drivers studied in prior research (Barkley & Cox, 2007) the fact that none of our participants would be considered a risky driver for this ELE calculator seemed highly unrealistic. In discussion with the developer, it was decided that a far better index of risky driving in our database was the number of times a participant had reported having his or her license suspended or revoked.
Alcohol	Never, rarely, 2-3 drinks/week 3-7 drinks/week, and 8+ drinks per week	Interview	

Note. ELE = estimated life expectancy; HLE = healthy life expectancy; LE = life expectancy; CC = community control; SCLI = Skinner Computerized Lifestyle Interview.

being evaluated and the average of the actuarial population on which the calculator is based. The UCONN HLE Calculator therefore provided four related dependent measures: (a) HLE or healthy years remaining, (b) ULE or unhealthy years remaining, (c) total years of life remaining (ELE), and (d) Relative Healthy Years Percent (RHYP) above or below the norm expressed as a positive or negative percentage. The HLE and ELE outputs were further adjusted for two variables within the calculator that may underestimate their contribution to ELE based on more recent research (Joshi et al., 2017). These were years of education beyond high school (with 11 months added per year) and smoking 20 or more cigarettes per day (with 2.4 years being subtracted; see Table 2). Those adjusted scores are henceforth termed HLE(A) and ELE(A).

Predictor Measures

The following measures were used to conduct the appropriate analyses for addressing the additional specific aims discussed above as possible variables associated with ELE.

Executive functioning in daily life. A self-report interview was created consisting of 91 items intended to reflect deficits in various components of EF as they may occur in daily life. More information on this interview can be found in other research from this study (Barkley & Fischer, 2011; Barkley et al., 2008). The internal consistency of this scale is high (Cronbach's $\alpha = .961$, $p < .001$). A factor analysis in that earlier research showed it to reflect five EF components, these being Time Management, Organization and Problem Solving, Self-Motivation, Self-Activation, and Behavioral Inhibition. Scores were created for each factor by counting an item as an EF symptom if it was reported as occurring often or very often. That earlier study also found that the H + ADHD group had more severe ratings on all of these EF components than did the H – ADHD and CC groups while the H – ADHD group scored more poorly than the CC group on three of the five components. This interview was subsequently transformed, normed, and published as the Barkley Deficits in Executive Functioning Scale (Barkley, 2011), the manual for which provides further information on the psychometric properties of this interview and the subsequent scale created from it.

Neuropsychological tests. The following battery of tests was used to evaluate verbal and nonverbal IQ as well as the EF components of inhibition, verbal and nonverbal working memory, fluency, and planning/problem solving.

Vocabulary and Block design subtests from the Wechsler Adult Intelligence Scale–Third Edition (WAIS-III). Two subtests were chosen from this standardized intelligence test to serve as a quick screening for level of verbal and nonverbal intelligence (Vocabulary and Block Designs; Wechsler, 1997). They were chosen for having among the highest correlations with the Verbal and Nonverbal IQ scores, respectively, derived from the complete test administration. The scaled scores from both subtests were used here.

Digit span from the WAIS-III. This test involves two subtests (Wechsler, 1997). In one, the examinee is given a series of increasingly longer strings of digits by the examiner at a rate of 1 per second. The examiner must repeat them back in the same numerical sequence. In the second subtest, the examinee must repeat increasingly longer strings of digits in a backward order from that given by the examiner. For both tests, the participant is given two trials at each span length. The test is concluded when the participant fails to repeat both trials correctly at that span length. The score is the longest span length the participant was able to perform correctly on at least one of the two trials. The raw scores from both tests were combined to form a single raw score for this measure. This test was chosen to evaluate verbal working memory.

Simon game. This is a commercially available game that consists of a circular plastic device housing four large colored keys on its top surface. Each key is a different color. When depressed, each of these keys emits a different tone. When activated, the game automatically presents a sequence of different tones and lights up the key corresponding to each tone as it does so. The participant must then press the keys in their correct sequence so as to reproduce the melody. With each trial, the sequence of tone/key combinations becomes increasingly longer and thus more complex. The score used here was the longest correctly reproduced sequence. This task was chosen so as to evaluate nonverbal working memory in a manner equivalent to a digit span forward task. It is akin to self-ordered pointing tasks (see Lezak, 1995). Our past research with adults with ADHD (Barkley, Murphy, & Kwasnik, 1996; Murphy, Barkley, & Bush, 2001) found those adults to be impaired relative to a control group on this measure. It is possible that some adults may be more familiar with this game than others, and so we inquired about this issue with our participants. The groups did not differ in their familiarity with this game.

Kaufman Hand Movements Test from the Kaufman Brief Intelligence Test. The Hand Movements Test is a well-standardized and normed test for children based on a traditional measure of frontal lobe function in adults (Kaufman & Kaufman, 1993). Children are presented with progressively longer sequences of three hand movements that they must imitate. The test has acceptable reliability and normative data and three studies have shown it to differentiate groups of ADHD from groups of normal children (Grodzinsky & Diamond, 1992; Mariani & Barkley, 1997) and from attention deficit disorder (ADD) children who are not hyperactive (Barkley, Grodzinsky, & DuPaul, 1992). Its sensitivity to ADHD may rest in the well-known fine motor coordination difficulties often seen in these children as well as in their inattention to the task itself or deficits in nonverbal working memory, especially as sequences of movements become progressively longer.

The 5 Points Test of design fluency. Originally developed by Regard, Strauss, and Knapp (1982) as an attempt to design a nonverbal version of more commonly used verbal fluency tasks, this test involves a sheet of paper with 40 five-dot matrices on it (Lee et al., 1997). Participants are required to produce as many different figures as possible by connecting the dots within each rectangle within a 3-min time limit. Not all dots have to be used and only straight lines between dots are permitted. No figures are to be repeated. If a violation occurs, participants are given a single warning on the first violation but the rules are not repeated after any further infractions. Scores are the number of unique designs created, the number of repeated designs (perseveration), the number of rule infractions, and the percentage of designs that are repeated designs (percent perseveration). Patients with frontal lobe dysfunction have a significantly higher percentage of perseverative errors than do neurological patients without frontal involvement and psychiatric patients (Lee et al., 1997). Using a modified version of this same task, Ruff, Allen, Farrow, Nieman, and Wylie (1994) also found the task to be sensitive to frontal lobe injuries and perhaps is more sensitive to right than left lobe involvement.

Tower of London Test. This test presents the participant with a stand on which there are three spindles of different heights along with three balls of different colors (red, blue, and green) that are arranged on two of these spindles (Shallice, 1982). The participant is then shown a diagram illustrating the goal or final position in which these balls are to be rearranged. In proceeding to rearrange the balls in that final sequence, the participant most do so in the fewest moves. The task requires that participants look ahead to determine the proper order of moves, and so it is considered a test of planning ability. The test has been used in a number of neuropsychological studies of children with ADHD where planning deficits have been noted (Grodzinsky & Diamond, 1992; Hervey et al., 2004).

Stroop Color Word Test. This test measures the ability to inhibit competing responses in the presence of salient conflicting information (Stroop, 1935; Trenerry, Crosson, Deboe, & Leber, 1989). The version and norms published by Trenerry et al (1989) were used here. The task is comprised of three parts. In the first part, the participant reads a repeating list of color names (e.g., red, blue, and green) printed in black ink. In the second part, the participant names the colors of a repeated series of Xs printed in an ink of those same colors. In the last or Interference condition, the participant must say the color of ink in which a color word is printed. For some words, the color of ink in which it is printed is the same as that of the word while for others, the color of ink differs from that specified by the word. This portion of the task is believed to reflect problems with the capacity to inhibit habitual or dominant responses (reading the word, in this case). We used the score from this last portion of the test (Interference) as a measure of behavioral disinhibition.

The results for the group comparisons on these tests are presented elsewhere (Barkley et al., 2008). They found that both the ADHD groups performed more poorly than the CC group on the verbal and nonverbal IQ subtests (see Table 1), the Simon Game, The 5-Point Design Fluency Test, and the WAIS-III Digit Span subtest, while not differing significantly from each other. Only the H + ADHD group performed more poorly on the Stroop Test compared with both the H – ADHD and CC groups. And the H + ADHD group performed worse than the H – ADHD group that was worse than the CC group on the Kaufman Hand Movements Test. There were no group differences on the Tower of London Test. Subsequent reanalyses covarying IQ did not materially alter these findings.

Comorbid psychopathology: Hostility, anxiety, and depression. To evaluate comorbid symptoms of psychopathology, we employed the Symptom Checklist–90–Revised (SCL-90-R; Derogatis, 1986). This self-report scale provides a global severity index as well as *T*-scores for nine specific scales of maladjustment (e.g., anxiety, paranoid ideation, interpersonal hostility, depression, etc.). Only the scores for the hostility, anxiety, and depression scales were used here as these are the most often elevated in research on adult ADHD (Barkley et al., 2008).

Results

ELE

As a starting point, we needed to show equivalence in ELE between these groups without making adjustments for any of the education, occupation, health, and lifestyle variables entered into the UCONN HLE Calculator. The starting ELE for each participant was determined based on the actuarial tables available for just their age and sex from the SSA tables for 2004 (the year closest to the completion date of this follow-up point) published at the SSA website (see https://www.ssa.gov/oact/STATS/table4c6_2004.html). A one-way ANOVA was used to compare the two diagnostic groups at study entry (H vs. CC) on this ELE score. Differences were not significant ($F = 1.51$, $df = 1/200$, $p = .22$; H: $n = 131$, Mean = 49.99, $SD = 2.10$; CC: $n = 71$,

Table 3. Means, Standard Deviations, and Statistical Test Results for the Four UCONN ELE Calculator Scores for the Hyperactive and Community Control Groups Formed at Study Entry.

Group:	Hyperactive		Control			
Measure	*M*	*SD*	*M*	*SD*	*F*	*p*
Healthy—HLE(A)	45.1	8.8	54.7	7.4	60.57	<.001
Unhealthy—ULE	5.4	2.0	4.2	1.1	21.23	<.001
Total LE(A)	50.5	7.9	58.9	7.2	55.28	<.001
RHYP	−20.2	13.9	−8.5	10.6	38.70	<.001

Note. UCONN ELE = University of Connecticut estimated life expectancy; *F* = results of the *F* test from the one-way ANOVA; *p* = probability value associated with the *F* test; HLE(A) = healthy life expectancy adjusted for smoking amount and years of education after high school; ULE = unhealthy life expectancy; Total LE(A) = total years of life expectancy adjusted for smoking amount and years of education after high school; RHYP = relative healthy years percent.

Mean = 49.66, *SD* = 1.27). Thus, without DALY/HALY adjustments for any other variables, and using government provided actuarial tables, the mean ELEs for these two groups are essentially equivalent.

An ANOVA was then used to compare the initial groups formed at study entry (H vs. CC) on the four measures computed from the UCONN HLE Calculator with adjustments as discussed above. Statistical significance was set a priori at $p < .01$ given the large number of analyses. The results of these group comparisons are shown in Table 3. All comparisons were significant (*p*s < .001), indicating that the H group had differed significantly from CC cases on all four ELE-related scores. On average, the H group demonstrated a nearly 10-year reduction in HLE(A), while having 1.2 years greater in ULE, thus resulting in an overall 8.4year reduction in Total ELE(A). On the RHYP score, the H group placed more than 20% below average compared with the CC group ($M = −8.4\%$).

The three groups that were formed at the young adult follow-up based on persistence of ADHD by that point (H + ADHD, H – ADHD, CC) were then compared on these same four ELE scores using one-way ANOVAs. The results are shown in Table 4 with group differences on all four scores being significant (*p*s <.001). Persistence of ADHD to adulthood had a significant impact on reducing HLE(A) and thus Total ELE(A) as well as on RHYP compared with nonpersistent cases of the disorder. But the persistence of ADHD at adulthood was not associated with a significant difference from the nonpersistent ADHD group in their ULE, with both differing significantly on this score from the CC group at follow-up.

Group Differences on ELE Calculator Variables

The next set of analyses focused on the 14 ELE calculator variables and the two additional ones (education beyond high school, smoking 20+ cigarettes per day) used to make further adjustments to the ELE output. These analyses explored the specific aim of what calculator factors were accounting for this reduction in ELE associated with the ADHD groups. We first compared the three groups formed at adulthood on the six dimensional measures used in the calculator using one-way ANOVAs. The p value was set at _<.05 due to the small sample sizes of these outcome groups and so reduced power. The results are shown in Table 5. The groups did not differ significantly in their age, weight, or height. However, both ADHD groups had significantly less education compared with the CC group. The ADHD+H group also had a significantly lower annual salary and consumed significantly more alcoholic drinks per week than did the CC group, while the ADHD – H group did not differ from either group, placing between the two on these variables.

We next compared the groups on the 10 variables used in the ELE calculator that were categorical in nature, using Pearson chi-squares (see Table 6). The groups did not differ in their sex, diabetes, or nutrition. However, both of the ADHD groups were less likely to graduate from high school and were more likely to be smokers than the CC groups, with neither ADHD group differing from the other in these aspects. The ADHD + H group reported significantly poorer current health than did the ADHD – H group and both ADHD groups reported poorer health than the CC group. This was also the case with regard to getting 8+ hr of sleep per night. Only the ADHD+H group had a higher percentage of smokers consuming 20+ cigarettes per day compared with the other two groups although the difference between the ADHD – H and CC groups was of marginal significance ($p = .053$). Although not significant, the two ADHD groups also had a higher percentage of cases reporting at least 2+ drivers' license suspensions/revocations than did the CC group that was of marginal significance ($p = .06$). These analyses reveal which calculator health and lifestyle factors were resulting in the significant reductions in ELE associated with the ADHD groups that might serve as targets for subsequent intervention efforts so as to improve ELE.

Background Traits Potentially Associated With ELE

Having shown which fisrt order factors in the ELE calculator were adversely affecting ELE in the ADHD-C groups, we then examined several second order trait variables that might be linked to reductions in ELE via their association with the health and lifestyle factors used to compute ELE. These background variables were IQ, EF components as measured via neuropsychological tests, ratings of EF in daily life, and several dimensions of psychopathology often associated with ADHD (hostility, depression, and anxiety). Before examining the relative contributions of these measures to ELE in the entire sample using multiple regression,

Table 4. Means, Standard Deviations, and Statistical Test Results for the Four UCONN HLE Calculator Scores for the H + ADHD, H – ADHD, and Community Control Groups.

Group:	(1) H + ADHD		(2) H – ADHD		(3) Community				Pair-wise
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Contrasts
HLE(A)	42.0	8.8	47.3	8.2	54.7	7.4	38.94	<.001	1<2<3
ULE	5.8	2.2	5.2	1.8	4.2	1.1	13.20	<.001	1,2<3
Total—LE(A)	47.8	7.9	52.4	7.4	58.9	7.2	35.30	<.001	1<2<3
RHYP	−25.6	13.4	−16.5	13.0	−8.5	10.6	29.48	<.001	1<2<3

Note. UCONN HLE University of Connecticut healthy life expectancy; H + ADHD = hyperactive group that currently has a diagnosis of ADHD at follow-up; H – ADHD = hyperactive group that does not have a diagnosis of ADHD at follow-up; *F* = results of the *F* test from the ANOVA; *p* = probability value associated with the *F* test; pair-wise contrasts = results from the pair-wise comparisons of the three groups; HLE(A) = healthy life expectancy adjusted for smoking amount and years of education after high school; ULE = unhealthy life expectancy; Total LE(A) = total years of life expectancy adjusted for smoking amount and years of education after high school; RHYP = relative healthy years percent.

Table 5. Group Differences for the Dimensional Measures Used in the ELE Calculator.

Group:	(1) H + ADHD		(2) H – ADHD		(3) Community				Pair-wise
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Contrasts
Age (years)	26.8	1.4	27.2	1.4	26.9	0.8	1.52	NS	
Weight (lb)	209.0	63.7	205.0	50.0	194.6	52.9	1.17	NS	
Height (ft)	5.8	0.4	5.8	0.3	5.8	0.2	0.52	NS	
Education (years)	12.3	1.9	12.9	2.1	15.8	2.3	49.06	<.001	1,2<3
Annual salary (thousands)	25.4	14.5	29.5	19.5	36.6	19.0	5.43	.005	1<3
Alcoholic drinks consumed weekly	9.7	16.8	4.3	6.2	5.5	7.1	4.40	.013	1>3

Note. ELE = estimated life expectancy; H + ADHD = hyperactive group that currently has a diagnosis of ADHD at follow-up; H – ADHD = hyperactive group that does not have a diagnosis of ADHD at follow-up.

Table 6. Group Differences for the Categorical Measures Used in the ELE Calculator.

Group:	(1) H + ADHD		(2) H – ADHD		(3) Community				Pair-wise
Measure	%	*N*	%	*N*	%	*N*	χ^2	*p*	Contrasts
Sex (male)	85	46	86	66	94	67	3.60	*ns*	
High school graduate	63	34	67	52	99	70	28.79	<.001	1,2<3
Exercise (3-4/week)	7	1	12	4	3	1	3.02	*ns*	
Health (excellent)	18	10	36	28	69	49	52.95	<.001	1<2<3
Diabetes (yes)	4	2	1	1	0	0	2.90	*ns*	
Nutrition (good)	31	17	48	37	51	36	6.53	*ns*	
Sleep (8+ hr/night)	48	26	67	52	86	61	20.48	<.001	1<2<3
Smokes cigarettes	65	35	57	44	35	25	12.36	.002	1,2<3
Smokes 20+/day	43	23	23	18	11	8	16.43	<.001	1>2,3
License revoked 2+ times	36	19	30	23	16	11	8.98	*ns*	

Note. ELE = estimated life expectancy; H + ADHD = hyperactive group that currently has a diagnosis of ADHD at follow-up; H – ADHD = hyperactive group that does not have a diagnosis of ADHD at follow-up; *ns* = not significant.

we examined the correlation matrix among the measures for possible collinearity within measures of a trait and multicollinearity across traits. As expected, most measures within each trait were more highly correlated with each other than with those of other traits, yet even then the tolerance for collinearity within traits and multicollinearity across traits appeared acceptable. Specifically, the EF ratings correlated more highly with each other (*r*s = .61-.77) than with EF tests (–.03 to –.31), IQ (–.11 to –.38), and SCL-90 scales (.42 to .59). The SCL-90 scales also correlated more highly with each other (.64-.75) than with EF tests (–.07 to –.21) and IQ (–.15 to –.23). However, the EF tests showed a

Table 7. Regression Analyses of EF Ratings, SCL-90-R Ratings, EF Tests, and IQ Subtests on to Total Life Expectancy (ELE[A]).

Predictors	B	t	p	95% CI	CT
EF Rating—Time management	−.192	−1.83	.069	[−.620, .023]	.267
EF Rating—Self-organization	.122	1.33	.184	[−.102, .527]	.353
EF Rating—Behavioral disinhibition	−.327	−3.13	**.002**	[−.842, −.191]	.269
EF Rating—Self-motivation	.115	1.17	.244	[−.273, 1.07]	.304
EF Rating—Self-activation	−.064	−0.66	.510	[−.743, .371]	.315
SCL-90-R—Depression	−.144	−1.52	.131	[−.236, .031]	.326
SCL-90-R—Anxiety	.120	1.34	.181	[−.040, .212]	.369
SCL-90-R—Hostility	−.168	−2.06	**.041**	[−.245, −.005]	.439
EF Test—WAIS-III digit span	−.021	−0.28	.782	[−.494, .372]	.515
EF Test—Simon: Longest correct	.036	0.55	.581	[0.331, .589]	.706
EF Test—5 points: Unique designs	.120	1.49	.139	[−.031, .219]	.449
EF Test—Stroop interference score	−.075	−1.28	.203	[−.267, .057]	.852
EF Test—Tower of London: Correct	−.069	−1.19	.236	[−.957, .237]	.870
EF Test—KHT: Number correct	.050	0.69	.489	[−.355, .740]	.556
WAIS-III: Vocabulary (verbal IQ)	.205	2.66	**.008**	[.131, .875]	.496
WAIS-III: Block Design (nonverbal IQ)	.028	0.36	.718	[−.336, .487]	.476

Note. EF = executive function; SCL-90-R = Symptom Checklist–90–Revised; ELE = estimated life expectancy; *B* = standardized beta coefficient from the final model; *t* = *t* test, *p* = probability value for the *t* test; 95% CI = confidence interval; CT = collinearity tolerance; WAIS-III = Wechsler Adult Intelligence Scale–Third Edition. Stroop = Stroop Word-Color Test; KHT = Kaufman Hand Movements Test. Estimate in the bold indicate results that were significant at $p < .05$.

similar range of correlations with each other (.13-.55) as they did with IQ (.10-.64); not unexpected given their similarity of measurement and known overlap.

We then used multiple regression with the entire sample (collapsed across groups) to analyze all trait predictor variables simultaneously for their relationship to total life expectancy indexed by Total ELE(A). The results appear in Table 7. The equation was significant ($R = .656$, $R^2 = .430$, $F = 9.14$, $df = 16/194$, $p < .001$) and explained 43% of the variation in Total ELE(A). Individual measures that were significant after controlling for all others as shown in Table 6 were the EF rating of Behavioral Disinhibition, the SCL-90-R rating of Hostility, and the Verbal IQ estimate. Given that this equation was significant, and to evaluate the amount of variance explained by each significant variable, we repeated this regression analysis using stepwise entry. Four of the variables were significantly predictive of Total ELE(A) explaining 40% of the variance, these being the EF rating of Behavioral Disinhibition ($R = .556$, $R^2 = .309$, $R^2\Delta = .309$, $F = 93.50$, $df = 1/209$, $p < .001$), the WAIS Verbal IQ estimate ($R = .607$, $R^2 = .368$, $R^2\Delta = .059$, $F = 19.53$, $df = 1/208$, $p < .001$), the SCL-90-R Hostility scale ($R = .621$, $R^2 = .386$, $R^2\Delta = .017$, $F = 5.90$, $df = 1/207$, $p = .016$), and the 5 Points Test score of Number of Unique Designs assessing nonverbal working memory ($R = .631$, $R^2 = .398$, $R^2\Delta = .012$, $F = 4.10$, $df = 1/206$, $p = .044$). Hence the second order background traits of Behavioral Disinhibition (EF), verbal IQ, comorbid hostility, and nonverbal fluency (EF) appear to make unique contributions to explained variation in total life expectancy.

Discussion

Consistent with our initial hypothesis, this longitudinal study found that children having hyperactive child syndrome, or ADHD-C, manifested a significantly reduced estimated HLE in remaining years, a significantly greater ULE in remaining years, and an overall significantly lower total life expectancy in remaining years than did control children by young adulthood. Also supporting our additional hypothesis, the persistence of ADHD to adult follow-up was associated with an even worse impact on these ELE measures than in cases where the disorder was not persistent in the originally hyperactive children. And both persistent and nonpersistent ADHD cases had significantly lower ELEs by adulthood than did control cases. This is the first study to compute estimated remaining years of life expectancy by adulthood in children with ADHD-C. Yet its findings are quite consistent with a few earlier studies discussed above, demonstrating a greater mortality risk in both children and adults with ADHD relative to the general population.

This study goes further, however, in showing that besides the causes of early mortality in previous research, those being chiefly accidental injuries and suicides, life expectancy by young adulthood in those having ADHD-C as children may be further compromised by various adverse demographic, health, and lifestyle variables that are used in estimating life expectancy. The situation is even worse for those in whom ADHD persisted to adulthood. A number of such adversities related to life expectancy were found here to be significantly and disproportionately associated with childhood ADHD-C by adulthood even if it had not persisted. These included the demographic factors of not only reduced education, lack of high school graduation, and annual income in the ADHD-C groups but also in the health and lifestyle factors of greater alcohol consumption, poorer overall health, reduced sleep, increased likelihood of smoking and of smoking more than 20+ cigarettes per day, and possibly greater adverse driving consequences resulting in license suspensions/revocations. These results provide insight into the reasons ELE may be reduced in those with ADHD-C. They also suggest avenues by which ELE could be improved via interventions.

Although sobering, the reduced ELEs found in this study to be linked to childhood ADHD-C as well as its persistence to adulthood are not immutable or necessarily stable going forward through adulthood. Many of the factors in estimating life expectancy that were shown to be more adverse in the ADHD-C groups can be changed and so yield significant positive effects on ELE. For instance, losing weight, increasing exercise, getting more sleep, reducing alcohol consumption, and quitting smoking are just a few of the health maintenance and self-improvement activities that might lead to improved ELE (Joshi et al., 2017). Yet such enthusiasm should not be unbounded, given our additional discovery of four background traits that accounted for substantial variation in life expectancy. These are more problematic in cases of ADHD-C and likely predispose those with ADHD-C to those adverse health and lifestyle problems that reduce ELE. Such background or second order traits may be more difficult to modify or ameliorate.

For instance, besides ADHD-C itself, this study showed that behavioral disinhibition (as assessed by EF ratings in daily life), verbal IQ, the comorbid psychopathology of hostility, and the EF of nonverbal fluency (and its association with nonverbal working memory) all uniquely contributed, in descending order, to variation in life expectancy. The largest percentage, however, by far was contributed by behavioral disinhibition. All are known to be more deficient or poorer in those having ADHD. Even so, treating ADHD symptoms and especially the larger domain of behavioral disinhibition might also improve ELE. Specifically, using ADHD medications and evidence-based psychosocial treatments, such as EF-focused cognitive behavioral therapy and Adult ADHD Coaching, could help to reduce ADHD symptoms and improve EF in daily life generally and behavioral disinhibition specifically so as to improve ELE. While lower verbal IQ and deficient nonverbal fluency may be more difficult to improve, they contributed far less to ELE variation than EF in daily life and thus may not be as crucial to change so as to improve ELE. Should any of the fisrt order risk variables or the second order trait factors change with age going forward, then ELE would change accordingly. At the very least, these results argue for more aggressively treating ADHD and its associated EF deficits as well as including health-related recommendations as part of the treatment proffered by clinicians for those with ADHD.

The limitations of this study should not be overlooked. ELE differences between groups may actually be greater than those evident here for two reasons. One is that variables known to affect elevated mortality risk generally (blood pressure, high density lipoprotein [HDL] and low density lipoprotein [LDL] cholesterol, coronary artery disease; Joshi et al., 2017) and those within ADHD samples (accidental injuries, suicide attempts; Barbaresi et al., 2013; Dalsgaard et al., 2015; Nigg, 2013) were not entered in the ELE calculator used here. Another is that young adults with ADHD have been shown to underreport the severity of their symptoms and even some types of impairment, such as driving, relative to reports about them from their parents (Barkley et al., 2002). Both reasons would have biased calculator inputs and hence outputs in a more conservative direction.

Another limitation is the reliance here on a clinically referred sample of children with hyperactivity/ADHD-C. They were defined by research criteria representing a severity of symptoms at or above the 97th percentile for age and so are likely to be more severe in their ADHD-C symptoms and to have higher rates of comorbid psychopathologies than is often the case using community derived samples and current diagnostic criteria for ADHD. Both factors may bias these results toward larger ELE reductions than would be the case in a community sample with ADHD-C or those identified as ADHD-C by current criteria. The overrepresentation of males in the study, our reliance on a largely White sample of Midwestern U.S. origin, and our focus only on ADHD-C cases in childhood all limit the degree to which these findings can be generalized to females with ADHD, to other presentations of ADHD, and to ADHD cases in other ethnic groups or other regions.

With these limitations in mind, the present study demonstrated that childhood ADHD-C (hyperactive child syndrome) is associated with reduced ELE by young adulthood, including healthy remaining years of life, as well as an increased period of unhealthy estimated years of remaining life. This reduction in ELE is worse when ADHD is persistent into adulthood. The reduced ELE linked to ADHD was found to be a function of the first order variables of less education, less annual income, greater consumption of alcohol and tobacco, diminished sleep, and poorer overall health status relative to the control group. Moreover, ELE was also shown to be a function of the second order traits of deficient behavioral inhibition in daily life and, much less so, of low verbal IQ, greater interpersonal hostility, and deficient nonverbal fluency. Our findings in general are consistent with research showing that various mental disorders have adverse effects on ELE (Chesney, Goodwin, & Fazel, 2014; Nordentoft et al., 2013).

Our results extend this earlier work by adding ADHD to this list. Nevertheless, our findings may also argue for the potential value of adding recommendations regarding health and lifestyle related self-improvement programs to the usual package of treatments applied to ADHD across development, given the apparent modifiability of many of these risk factors linked to reduced ELE.

Authors' Note

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Notes

1. https://gateway.euro.who.int/en/indicators/hfa_67-1,080-disability-adjusted-life-expectancy-world-health-report/
2. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2486718/
3. https://en.wikipedia.org/wiki/Disability-adjusted_life_year

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