COGMED working memory training in children with Attention Deficit/Hyperactivity Disorder (ADHD): a feasibility study in Saudi Arabia

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Abstract

Working memory training has been proven effective for improving cognitive functioning in patients with Attention Deficit/Hyperactivity Disorder (ADHD). However, the feasibility of this type of training for children in Saudi Arabia has not been previously explored. We investigated the feasibility of implementing Cogmed Working Memory Training (CWMT) in a sample of 29 Saudi children with ADHD. We found no significant demographic or clinical differences between compliant and noncompliant children. Although compliant children were initially better at following instructions and reported better improvements in working memory and math skills compared to those who did not complete the CWMT, all children who participated in the program showed improvements in performing the CWMT tasks. Most parents found the Cogmed training feasible for their children, were satisfied and keen to continue with the program, and felt the training helped them to address their problems. Most children did not encounter any difficulties in using the software, and many families were, therefore, likely to continue using the techniques from the program. We conclude that CWMT for children with ADHD is feasible in Saudi Arabia. Larger case-controlled studies are needed to thoroughly investigate the effects of CWMT compared to other interventions in Saudi children with ADHD.

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Keywords: ADHD; working memory; cognitive training; Cogmed; feasibility

Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental condition characterized by age-inappropriate inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013). Children with ADHD display several alterations in cognitive functioning (Frazier, Demaree, & Youngstrom, 2004) that are likely to affect mental health, social and interpersonal skills, as well as behavioral and academic performance, with consequences that might also persist until adulthood (Erskine et al., 2016). Amongst others, working memory (WM) is an executive function found to be deficient in children with ADHD. WM describes the mental ability to temporary store and manipulate information, and it is essential for several aspects of everyday life functioning, including paying and maintaining attention, problem-solving, learning and decision making (Cowan, 2014). Deficits in working memory have been widely reported in ADHD (Cortese et al., 2015) and are likely to predict academic and learning difficulties (Schreiber, Possin, Girard, & Rey-Casserly, 2014), impulsive decision-making (Fabio et al., 2020) and inattention symptoms (Tillman, Eninger, Forssman, & Bohlin, 2011).

Recently, there has been growing interest among healthcare professionals, parents of children with ADHD, and researchers for interventions that target WM. WM training is associated with improvements in cognitive function, generalized benefits to everyday life functioning (Sonuga-Barke, Brandeis, Holtmann, & Cortese, 2014), and improvements in ADHD-related inattention (Spencer-Smith & Klingberg, 2015). The mechanisms underlying the effectiveness of WM training are likely to be associated with neuro-plastic changes in functioning of pre-frontal and frontal brain systems involved in attentional control and higher-level executive functions (Klingberg, 2010).

That said, studies have demonstrated that interventions that target only a single cognitive domain (e.g., WM) are often not effective in producing positive effects on other cognitive functions or domains (such as academic performance), a process which is usually defined to as 'far transfer.' The mechanisms underlying transfer and generalization effects of cognitive interventions are not yet well known (Simons et al., 2016). Despite this, interventions based on cognitive training have been shown to produce improvements in 'near-transfer' tasks (i.e., tasks similar to those practiced during the training), which, although they may not persist long-term, are associated with general improvement of abilities in daily life (Bharadwaj, Yeatts & Headley, 2021; Simons et al., 2016).

Several WM training programs have been developed, amongst which Cogmed Working Memory Training (CWMT; Klingberg et al., 2005) is one of the most widely implemented and investigated. CWMT is self-paced and can be delivered on any laptop/computer and is user-friendly. CWMT is comprised of computer-based visuo-spatial and verbal working memory tasks, and it has been found effective in improving performance on 'near-transfer' tasks and working memory capacity, although effect sizes may be small (Aksayli et al., 2019). Spencer-Smith & Klingberg (2015) conducted a systematic review of the literature and meta-analysis to investigate the effects of CWMT for people with ADHD, and found that CWMT is effective in improving inattention in children and adults with ADHD, with generalized benefits to everyday functioning. Specifically, they included 12 studies and found a significant effect of CWMT on inattention in daily life (regardless of having, or not, ADHD), which persist at follow-up after the training ended. Moreover, benefits of CWMT have been found for visuospatial and verbal working memory,

Studies exploring the feasibility of non-pharmacological approaches to management of ADHD and specifically those pertaining to cognitive intervention among developing countries are sparse, if any. Saudi Arabia is a rapidly developing country which is thought to be the lead in improving public healthcare provision among neighboring countries. The overall prevalence of ADHD in Saudi Arabia has been found to be between 3.4 and 5% in primary school children

(Albatti et al., 2017; AlZaben et al., 2018), in line with what is reported worldwide (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). Many studies exploring ADHD in Saudi Arabia have been limited to investigating either the epidemiology of the condition (Albatti et al., 2017; AlZaben et al., 2018) or the public awareness of ADHD among medical students (Alsuhaibani et al., 2020), caregivers (Al-Mohsin et al., 2020), healthcare professionals (Al-Ahmari et al., 2018) and teachers (Alanazi & Al Turki, 2021; Munshi, 2014). These studies found that the knowledge-base of physicians as well as of primary school teachers (professionals that are the first point of contact for parents of children with ADHD) are regarded as insufficient (Alanzi & Al Turki, 2021; Al-Ahmari et al., 2018). Studies that investigate general knowledge and opinions about ADHD in Saudi Arabia show that the country is still in the exploratory stage of research on interventions for ADHD. To the best of our knowledge, there is no study in Saudi Arabia that has introduced such an interventional technology as CWMT for ADHD.

Currently, pharmacological treatment is the most feasible and favorable approach for dealing with patients with ADHD in Saudi Arabia (Alqahtani, 2017). While medication use is regarded as having a good benefit-to-risk ratio, the possibilities of an increased risk of developing a substance addiction later in life, as well as an increased potential for developing psychiatric disorders, are still being discussed (Krinzinger et al., 2019). That said, there are growing concerns from parents about the pressure from schools to start children on medication (Alqahtani, 2017). A study conducted by Al-Mohsin et al. (2020), for example, reported growing concerns among mothers regarding the side effects of medication, which could potentially hinder compliance (Al-Mohsin et al., 2020). Moreover, the majority of parents of children with ADHD prefer avoiding the use of medication, and they have been found to have limited knowledge as well as limited access to psychological intervention (Alharbi, 2018). Similar concerns have been expressed by teachers (Munshi, 2014).

A recent study published by Bashiri et al (2021) proposed to adopt national guidelines for the management of patients with ADHD in Saudi Arabia. However, in line with current practices in Saudi Arabia, they did not acknowledge the role of computerized cognitive based intervention as a possible non-pharmacological approach for ADHD (Bashiri et al., 2021). The treatment recommendations of other countries have been including computerized WM training, as well as a more differentiated view on behavioral interventions and new technologies, like neurofeedback, for some years now. Importantly, several guidelines have emphasized that medication does not necessarily have to be the first choice of intervention for patients with ADHD (Feldman et al., 2018; AWMF Guidelines, 2017; NICE Guidelines, 2019), but this was not specified in the recommendations by Bashiri and colleagues. A feasibility study on CWMT can bring computerized therapy and other new measures and standards to the attention of local specialists in Saudi Arabia. It might also lead the way for other Middle Eastern countries with a similar state of research as Saudi Arabia. A systematic literature study by Alkhateeb & Alhadidi (2016), for example, found a general lack of research on ADHD in 14 Arab countries. Most Arab countries have not yet published consensus treatment guidelines and have just recently started researching cognitive intervention for ADHD, hence the lack of studies in this area. Furthermore, in countries such as Saudi Arabia where pharmacological treatments for ADHD is still prioritized, it is important to explore self-paced and home-based interventions that that may lead to enhancements in working memory and, potentially, reductions in ADHD-related symptoms.

The present study is, to our knowledge, the first to investigate the feasibility of implementing CMWT in a sample of Saudi children with ADHD. Firstly, we aimed to verify if CWMT was feasible for the sample of children recruited, namely if most of children enrolled in the training program would be able to complete it. Secondly, we aimed to investigate secondary factors that could have potentially influence adherence to the program, including having completed the training. We therefore compared children who were categorized as 'compliant' (i.e., completing at least 80% of the program) with children who were categorized as 'non-compliant' on a series of outcome measures, including demographic and clinical characteristics, but also changes in working memory performance due to the training, to investigate if being able to complete the CWMT was indeed associated with improvements in working memory. This study has the potential of providing useful information on the generalizability of the effectiveness of CWMT, which, upon thorough examination and assessment, could be used in Saudi Arabia as a promising intervention to improve working memory in children with ADHD. Moreover, the results of this pilot study will determine the feasibility of carrying out future trials to systematically investigate the effects of CWMT on working memory, attentional abilities and ADHD symptoms in Saudi children.

Materials and Methods

Study Design & Ethical Approval

This is a feasibility trial with an uncontrolled, within-group design. Ethical approval for this feasibility study was obtained from the Unit of Biomedical Ethics at King Abdelaziz University.

Study Sample

The study was advertised at the pediatric clinic at King Abdulaziz University Hospital (Jeddah, Saudi Arabia). In addition, electronic flyers with the study information and researcher's contact details were distributed among those attending ADHD awareness events. Participants who expressed interest were screened by phone for inclusion criteria and invited to the clinic for demonstration of the software used for the training. Inclusion criteria (based on previous studies, see for example; Chacko et al., 2014) were: a) being between the age of 7 and 15 years of age; b) having a previous confirmed diagnosis of ADHD made by a healthcare professional based on at least DSM-IV diagnostic criteria and further confirmed prior to enrolment in the study by the NICHQ Vanderbilt Attention Deficit/Hyperactivity Disorder Rating Scales (VADRS; Wolraich et al., 2003); and c) having internet access at home.. Children with severe sensory disabilities, such as severe hearing and vision impairments or severe intellectual disabilities, were excluded. Demographic and socioeconomic information about the children were collected at baseline, including gender, clinical history and current care, co-occurring diagnoses, medication history, and education (regular or special). In addition, information on the socio-economic background of the child's family (reported in Table 2) was collected based on a previously published scale adapted to the Saudi culture (Alomar, Parslow, & Law, 2018).

The Training Program

Cogmed (Klingberg et al., 2005) is a computer-based training program aimed to train working memory. For this study, we adopted the Cogmed RM training protocol (Roche, Johnson, & Working, 2014). Trainees were asked to accomplish eight daily tasks within 45 minutes for 5 days a week for a duration of 5 consecutive weeks. The Cogmed RM is designed for school-age children (7-18) and is comprised of verbal and visuospatial working memory tasks in a space-theme and game-format design, whose difficulty is automatically adjusted to each child working memory abilities on each task, for each session.

Children who attended the clinic for the demonstration of Cogmed RM had the study explained to them and were given the opportunity to attend a trial session, which was an opportunity to answer any questions or concerns expressed by the parents or to resolve any technical challenges the parents may face when running the program at home. Researchers ensured that all children had active access to the internet service. Contact details of the researchers were given, and parents were advised to contact them whenever they had an issue running the tests at home. For those who agreed to participate, a consent form was signed by the parents. Children attended the CWMT program individually at home and received feedback from a certified Cogmed coach. No specific instruction was given regarding the timing of each session, as long as the session was completed on the same day.

Outcome Measures

ADHD Clinical Assessment

ADHD was assessed through the parent- and teacher-informed VADRS (Wolraich et al., 2003). VADRS is based on the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV-TR; American Psychiatric Association, 2000). VADRS is an assessment tool for ADHD symptoms and their effects on the child's behaviors and academic performance. It also measures the presence of co-occurring conditions associated with ADHD such as ODD, CD, anxiety and depression. The VADRS has two forms: parents and teachers. In each form, there are two sections: "symptoms assessment" and "behavioral and academic impairments". The questions are related to the subtypes of ADHD: the inattentive subtype, and the hyperactive-impulsive subtype. The rating scale includes four items: 0: never, 1: occasionally, 2: often, and 3: very often. The first two items are considered negative and the last two items are considered positive. In order to meet diagnostic criteria for ADHD on the VARDS, the subject should score six positive symptoms out of nine symptoms of either the inattentive subtype, or the hyperactive-impulsive subtype, or both for the combined subtype. In each comorbid condition, the subject should score three or more positive symptoms. In the performance section, the rating scale is: 1-2: above average, 3: average, 4-5: problematic. The subject should score at least one "problematic" which is equivalent to positive symptom indicating an impairment in interaction and academic performance. Through the VADRS, parents and teachers were asked to provide information on the child's symptoms of ADHD, oppositional defiant disorder (ODD), conduct disorder (CD) and anxiety/depression. Prior to the intervention, parents and teachers filled up the VARDS, and this was repeated at follow-up, after completing the study. Good internal consistency and validity have been reported for the parent- and teacher-versions of the VADRS (Wolraich et al., 2003; Wolraich, Bard, Neas, Doffing, & Beck, 2013).

Compliance and Performance Improvement

Children's compliance to the training was assessed through the Compliance Index (the number of training sessions completed overall) and the time spent on the training program. Specifically, we calculated the time spent by each child working on the training tasks (active time), the time taken by the child as a break between tasks (pause time) and the overall training time (active + pause). This has been done in relation to each individual session (i.e., averaged across all sessions) and in relation to the whole program (total time). Children's performance and improvement throughout the training was assessed with the Cogmed Start Index, the Max Index and the Improvement Index. The overall Improvement Index is automatically computed by the software and is calculated by subtracting the Start Index (average scores on the three best trials on days 2 and 3 of training) from the Max Index (average scores on the three best trials during the two best days of the overall training, excluding days 2 and 3 of training). As per the original protocol (Klingberg et al., 2005), a child was defined as compliant if they completed at least 80% of the whole training.

The Cogmed Progress Indicator (CPI) is an automatically calculated measure of performance, improvement and transfer on some tasks performed by the children after the CWMT (assessing working memory, the ability to follow instructions, and mathematical skills). On training days 1, 2, 10, 15, 20 and 25, children were asked to perform such tasks (which were not part of the training), and feedback was recorded by the software and provided to children and their families. For each task, a Start Index, a Max Index and an Improvement Index were calculated. The Improvement Index was calculated by subtracting the Start Index (average scores on the three best trials at the beginning of the training) from the Max Index (average scores on the three best trials during the two best days of overall training).

Post-training cognitive and clinical assessment, and parental perspectives

According to the original study protocol, we had planned to invite children and their parents after the end of the CWMT for a secondary assessment with the VADRS. Unfortunately, this was not possible due to COVID-19 lockdown regulations placed in Saudi Arabia in 2020/2021, when the second stage of the study was planned. We adapted the protocol to this unprecedented situation and asked parents to provide feedback on the training by answering six questions during a phone conversation (four questions on a Likert Scale and two open-ended). These questions investigated parents' satisfaction and willingness to continue with the program and asked them to indicate if they encountered any issues or problems using the software or if they had any other feedback (for more details, see Appendix A).

Statistical analyses and sample size

Because of our small sample size, we used non-parametric tests for bivariate analysis. According to the type of outcome variable investigated, independent-samples Mann-Whitney U tests, related-samples Wilcoxon signed rank tests, and Fisher's exact tests were used to investigate differences between groups of children who were categorized as "compliant" and "non-compliant" on VADRS scores (total and subscales), sex, ADHD subtype, clinical care, co-occurring conditions, education, parental education and occupation, type of house, number of cars owned, and other ownerships. Then, we compared the groups on the time spent on the training (including active training time, pause time, and total time), for the overall program and averaged across sessions; and on indices of overall performance (Cogmed Start Index, Max

Index and Improvement Index) and transfer effects (Cogmed Progress Indicators for working memory, following instructions and math skills). We also estimated the correlation between all continuous variables by using Spearman's correlation tests. SPSS (IBM) v27 was used for data entry and analysis, and an alpha level threshold of 0.05 was used to detect statistical significance. More details can be found in each of the respective paragraphs in the Results section.

Results

Demographic and clinical characteristics

Twenty-nine children (10.56 ± 2.62 years old; 13.8% females) were enrolled in the study and all initially participated in the Cogmed training. There were no significant differences on clinical and demographic measures between 'compliant' (n = 18) and 'non-compliant' children (n = 11) (see Table 1 and 2 for full results). Children were considered 'compliant' if they completed at least 80% of the program. Three children were excluded from further analyses because they did not start the training at all (n = 2) or they only completed one session (n= 1), therefore no sufficient information could be collected.

[Tables 1 and 2 here]

Training Compliance and Engagement

Children were involved in the CWMT for an average of 51 minutes per session (range: 32 min – 108 min), including an average of 39 minutes of active training (range: 30 min – 52 min) and an average of 12 minutes of pause time (range: 1 min – 70 min). Overall, children completed on average 2.71 sessions per week (range: 0.8 – 6.3). No significant differences were found between 'compliant' and 'non-compliant' children in relation to average active training time, pause time and overall training time per session (Table 3). However, as expected, 'compliant' children spent overall more time on the training compared to 'non-compliant' participants (Mann-Whitney $U = 3.000$; $p < 0.001$, Table 3). It is worth noting that no specific instructions were given to participants with regards to the minimum or maximum time spent on training, as long as the training session was completed.

[Table 3 here]

Performance Improvement

When investigating performance to the CWMT and improvements due to the training across the entire sample, we found a significant difference between the Cogmed Start Index (average scores on the three best trials on days 2 and 3 of training) and the Cogmed Max Index (average scores on the three best trials during the two best days of the overall training) (Wilcoxon Signed Ranks $Z = -4.459$; $p < 0.001$), suggesting that performance on the Cogmed tasks improved in the whole sample. There were no statistically significant differences between 'compliant' and 'non-compliant' children on the Cogmed Start Index (Mann-Whitney $U = 65.500$; $p = 0.724$), while 'compliant' children showed increased Cogmed Max Index (Mann-Whitney $U = 33.000$; $p = 0.030$) and Cogmed Improvement Index (Mann-Whitney $U = 35.500$; $p = 0.041$) compared to 'non-compliant' children (Table 4). These results suggest that, although performance to the Cogmed training program was similar at baseline amongst all children, those who completed at least 80% of the training showed more improvement to the training tasks than those who did not.

[Table 4 here]

Table 5 describes the Cogmed Progress Indicator (CPI), a measure of generalizability and transfer of training effects, for the tasks assessing working memory, ability to follow instructions, and mathematical skills. Performance on these non-trained tasks improved during the training in the whole sample of children (CPI Working Memory: Wilcoxon Signed Rank

Test Z = -4.019; p < 0.001; CPI Following instructions: Wilcoxon Signed Rank Test Z = -3.921; p < 0.001; CPI Math: Wilcoxon Signed Rank Test Z = -3.920; p < 0.001). Since we noted high variability in some CPI measures, particularly CPI Math Improvement Index, and CPI Following Instructions Improvement Index (Table 5), we examined whether this was related to age differences in our sample. However, the bivariate correlation analysis we conducted did not show any correlations between Age ~~did not significantly correlate~~ and ~~with any~~ CPI measures~~, having weak correlations on average~~ (~~mean~~ all r ~~=~~ ≤ 0.130, Supplementary File 1~~, SD = 0.131~~). ~~We have included a supplementary file that includes a summary of the analysis we conducted to investigate bivariate correlations between clinical/demographic indices and indices of performance and compliance to the training (Supplementary File 1).~~ Therefore, we decided against an additional control for age. While other clinical or demographic variables may have contributed to the increased standard deviations, sample sizes in the present study did not permit further investigations. However, we found statistically significant differences between 'compliant' and 'non-compliant' participants on several CPIs. As indicated in detail in Table 5, compared to 'non-compliant' children, 'compliant' participants had higher scores on Working Memory Max Index and Improvement Index, Following Instructions Start Index, Max Index and Improvement Index, and CPI Math Max Index and Improvement Index.

[Table 5 here]

Factors associated with improvement and compliance

When investigating potential associations between clinical/demographic indices and performance/compliance to the training (through bivariate Spearman correlations; see Supplementary File 1), we found that children with more severe hyperactivity/impulsivity had lower CPI Working Memory (r = -0.517, p = 0.007) and CPI Following Instructions (r = -

0.470, $p = 0.015$) at baseline, and lower CPI Math max ($r = -0.511$, $p = 0.008$), while those with more severe anxiety and depression had reduced CPI Following Instructions at baseline ($r = -0.393$, $p = 0.047$). Having completed more sessions of the training was associated with higher Cogmed Max index ($r = 0.403$, $p = 0.041$), Cogmed Improvement Index ($r = 0.415$, $p = 0.035$), CPI Working Memory Improvement Index ($r = 0.511$, $p = 0.008$), CPI Following Instructions Improvement Index ($r = 0.471$, $p = 0.015$), and CPI Math Improvement Index ($r = 0.647$, $p < 0.001$). Those children who had overall higher training time had higher Cogmed Max Index ($r = 0.425$, $p = 0.031$), Cogmed Improvement Index ($r = 0.420$, $p = 0.033$), CPI Working Memory Improvement Index ($r = 0.401$, $p = 0.042$), CPI Following Instructions Improvement Index ($r = 0.418$, $p = 0.033$), and CPI Math Improvement Index ($r = 0.490$, $p = 0.013$). Full results are reported, as a correlation table, in Supplementary File 1.

Parents' feedback

Twenty-one parents agreed to take part in our phone survey after the study ended. Parents who did not agree to take part were those whose children did not complete the training program. Seventeen parents (81%) reported that their child did not encounter any difficulties or challenges in using the software and carrying out the planned activities, while four parents reported that their child was stuck sometimes (n=2) or that the duration of training was slightly too long for their child (n=2). Most parents (n=14) reported having been 'extremely satisfied' with the training program, while the others were 'very satisfied' (n= 5) or 'moderately satisfied' (n=2). The program was found to have addressed the parents' problems overall well, with 12 parents reporting that the training program addressed their problems 'extremely well', five reporting 'very well', three reporting 'moderately well' and one reporting 'slightly well'. Most parents were 'extremely likely' (n=12) or 'likely' (n=7) to continue using the techniques from the program, with only two parents reporting it 'unlikely' (n=1) or 'extremely unlikely' (n=1), and most of them were ‘extremely likely’ (n=14) or ‘likely’ (n=5) to recommend others to use the program.

When analyzing the parents’ feedback on the overall program, some parents (n=2) reported that the session duration was slightly long, while others (n=2) reported that the program was “good but short in duration”. Moreover, one parent evaluated the program as “excellent” and five observed an improvement in their child’s attention due to the training. Two other parents observed improvements in their children, in the period when they were involved in the training, but they reported that after the end of the program the children “went back as before”. Lastly, one parent reported that they would have liked to receive assistance in running the software and carrying out the program at home.

Discussion

The present study was aimed at obtaining preliminary evidence about the feasibility of implementing Cogmed Working Memory Training (CWMT) in Saudi Arabia. In a sample of 29 children with ADHD in Saudi Arabia, we investigated compliance to the training, improvements due to the training, and parent satisfaction.

Most children who were recruited for the study were able to complete the training, with adequate compliance to the training shown by most participants (62%) who completed at least 80% of the program. Other studies investigating CWMT in a population similar to ours (children 7 to 13 years old, majority of the combined ADHD subtype, majority of male participants) reported compliance rates of above 90% (van Dongen-Boomsma et al., 2014; van der Donk et al., 2015; Egeland et al., 2013). Potential contributors to these quite different compliance rates might include the fact that their sample included less participants with co-occurring conditions (92.3% without comorbidities in van Dongen-Boomsma et al., 2014;

complete exclusion in Egeland et al., 2013). Moreover, they did not include patients with co-occurring conditions which are usually associated with behavioral difficulties, e.g., ODD or CD, which was done in our study. In van Donk et al (2015), for example, 21.1% participants suffered from dyslexia, out of 26.4 % that had a co-occurring condition, while van Dongen-Boosma et al. (2014) only reported one participant with co-occurring ODD and one with co-occurring nocturnal enuresis (3.8% each). Van der Donk et al. (2015) also reported a higher Cogmed mean Start Index (72.62, SD = 9.26), which might suggest less severe cognitive difficulties in their sample, although the high SD might render this difference statistically insignificant. Additionally, 76% of our sample was not under any current medical or psychological intervention for ADHD, suggesting that ADHD symptoms in our sample could have been slightly higher due to the absence of current interventions, which was the case in other studies. More severe ADHD symptoms could be an explanation for difficulties with adherence and compliance to the CWMT. However, another study (Bigorra et al., 2016) reported a compliance rate above 90% and it solely including children with an ADHD-combined subtype (60% female) who had never received psychological treatment or medication, with 31.43% diagnosed with co-occurring ODD. Anyway, the high number of untreated children in our study emphasizes the need for alternative interventions (besides medication and psychological interventions) and education on available ADHD interventions.

We did not observe any difference between those who were or were not defined as 'compliant' on clinical and demographic characteristics such as sex, ADHD subtype, ADHD symptoms, prevalence of co-occurring conditions, type of clinical care or education, parental education level and occupation, and socio-economic background (Table 2), suggesting that the commitment and motivation to complete the training were not associated with ADHD severity, global functioning or socio-economic background (Table 2). However, due to this being a feasibility study and the resulting small sample size, further investigations into group-differences were not possible. Therefore, we cannot rule out the possibility that some (or a combination of) these factors may have had a confounding effect on compliance. We address this limitation in more detail further below. That said, seventeen children, out of 18 'compliant', completed all the 25 sessions of the program, indicating that CWMT was indeed feasible for our sample of children with ADHD. Furthermore, no technical difficulty or challenges were reported by participants' parents as per post training assessment scale.

Across the whole sample, we observed an improvement in the performance on the Cogmed tasks and on the tasks that were not part of the training (i.e., those targeting working memory, following instructions and math skills), suggesting the benefits of CWMT on several cognitive functions, regardless of the completion rate. This is in line with previous studies showing the benefits of CWMT on working memory, cognitive and adaptive functioning in children with ADHD (Sonuga-Barke, Brandeis, Holtmann, & Cortese, 2014; Spencer-Smith & Klingberg, 2015; Klingberg, 2010; Klingberg et al., 2005). While our study was not designed to test 'far-transfer', it supports the findings of 'near-transfer' in previous studies (Aksayli et al., 2019; Bharadwaj et al., 2021; Simons et al., 2016). It should be noted that there was a high variability in individuals in terms of the Improvement Index, specifically pertaining to Following Instructions and Math. While our investigation showed that this was unrelated to age, it is possible that other sources of variability between individuals that could not be captured in the present data may influence these variable rates of improvement. Future studies in this area should attempt to elucidate predictors of improvement both to target interventions appropriately and to improve the sensitivity of statistical analyses.

Our ADHD sample was a fair representation of the ADHD community in terms of subtypes as most of the children in our sample had a diagnosis of ADHD Combined subtype, and the incidence of co-occurring conditions is in line with what has been reported for other clinical samples in Saudi Arabia (AlZaben et al., 2018). However, our study also demonstrated that being ‘compliant’, namely completing at least 80% of the training, was associated with better improvements on the Working Memory task, the Following Instruction task, and the Math task. Those children who were able to complete more sessions were also likely to display a larger improvement on working memory performance and displayed stronger transfer effects on other cognitive functions. Thus, the protocol initially proposed for CWMT (Klingberg et al., 2005) has been demonstrated both feasible and beneficial for improving working memory skills in our sample.

Having completed more sessions of the training was associated with improvements on several performance indices (both directly and indirectly targeted by the training), with higher training time being found continuously associated with such improvements. It would be interesting to investigate, in larger samples, if specific factors are likely to predict compliance to the CWMT (and, therefore, time spent on the training). Some children may, in fact, only benefit from the CWMT if they initially show a certain level of sustained attention and ability to control hyperactivity and motor behavior (initially achievable through pharmacological intervention but possibly maintainable through working memory training).

In this study, neither the pharmacological treatment nor the co-occurring conditions had a significant impact on the outcomes. However, it is worth mentioning that a very small percentage of our sample was on either one of these treatments, while most of the sample (20 out of 29) were receiving no treatment at all, potentially explaining why such association was not found to be significant. That said, parents may be hesitant to start pharmacological treatment for their children in fear of long-term effects (van der Donk et al., 2015) and options such as behavioral therapy may not be feasible due to higher cost than Cogmed or limited resources, which makes interventions such as Cogmed more likely to be accepted and feasible for the Saudi population as demonstrated by the fair compliance rate of this study and parent satisfaction. As recently suggested, self-guided interventions (such as Cogmed) have the advantage of being user-friendly and accessible to the general population and, hence, the small statistical effects these interventions have may be of great significance for health outcomes (Nordby, Kenter, Lundervold, & Nordgreen, 2021). Furthermore, the cost of COGMED program could be considered affordable, if provided on an institutional level.

It should be acknowledged that the present study had some limitations. By designing this as a feasibility study and comparing only two small groups of 18 and 11 children, without implementing a control condition, the statistical power of this study is fairly limited. The reduced power might have prevented us from detecting possible differences between compliant and non-compliant groups with regards to clinical and demographic factors. This is a shortcoming that our study shares with the CWMT studies criticized by Simons et al. (2016). We did not find significant differences between groups in terms of any clinical or demographic variables measured. However, while groups were evenly matched on these dimensions, it is still possible that inattention, hyperactivity/impulsivity, or other factors could impact outcome measures, even if its impact was consistent between groups. Future studies might want to identify and control any potential confounds in statistical analyses to more clearly delineate the impact of intervention, in the absence of such possible confounds. They should, therefore, focus on recruiting larger and more clinically heterogeneous samples, as well as compare groups of children involved in the CWMT with those involved in other activities or on a waiting list. Stratification by clinical severity (e.g., number of comorbidities) would be of advantage to differentiate the possibility of "pure" improvements through CWMT from the confound of increased feasibility via low clinical severity. This might also help to clarify the differences in compliance rates we have noticed between ours and other studies. Furthermore, in our study we had a very small proportion of female participants (14%) which may limit the generalizability of the intervention to both genders. Larger case-control studies can address these limitations.

A previous study on the efficacy of CWMT in young patients (Chako et al., 2013) found that the training aid and coaching has an important role for children with increased behavioral problems. Compliance in this study may have been affected by how the parent supported the child during the home-based program, but we did not have any chance to measure this since we could not directly monitor the children during the program. The COVID-19 pandemic started to impact Saudi Arabia just shortly after the start of our study, and this could have affected the compliance rate in our study. Similarly, due the COVID-19 pandemic, we were not able to obtain clinical and improvement indices post-training, as planned in the original study design. We could not carry out the intervention as planned and were only able to collect data from the Cogmed software platform, without independent rating of child's behavior at home or at school pre- and post-training and without including other measures of executive functioning. It will be crucial to address these limitations in future research studies aimed at thoroughly investigating the effects of CWMT and other forms of cognitive and working memory training on different aspects of cognition, behavior and adaptive functioning. Randomized and blinded controlled trials are needed to investigate the effects of CWMT in comparison and addition to other interventions (including but not limited to pharmacological intervention and other types of cognitive training), and to investigate long-terms effect of CWMT on cognitive and adaptive functioning.

Despite these limitations, we believe that our study has a crucial clinical relevance in Saudi Arabia. The CWMT is a self-paced program which is usually carried out at home (supervised by a tutor); it is user-friendly and inexpensive. Having demonstrated that it is also feasible and effective, is encouraging and suggests that CWMT could be beneficial for children with ADHD living in Saudi Arabia, where pharmacological interventions is usually prioritized. This is likely to be a first step to acknowledge to Saudi Arabian clinicians and families of children with ADHD that Cogmed (and cognitive interventions in general) are feasible and effective options in alternative to medication and are well received by parents. In the future, we suggest designing randomized studies (including RCTs) to consolidate the evidence we have obtained through this pilot feasibility study. We were also able to collect parent's qualitative feedback on the program. A substantial number of parents reported being not only satisfied with the program but also said that that the intervention helped them tackle challenges related to ADHD in their children. Most participants also reported not having had any technical challenges in using the Cogmed software, suggesting the feasibility of the original protocol. These findings are in line with previous studies on Cogmed-based interventions for children with ADHD (Benyakorn et al., 2018).

Conclusions

To our knowledge, this is the first study investigating the feasibility and effects of CWMT on a Saudi ADHD pediatric sample, and replicating the promising results on near-transfer already reported in several other countries worldwide. Sharing our preliminary findings (and those emerging from future studies) with policy makers, is likely to direct more attention to non-pharmacological interventions for ADHD in Saudi communities, which currently receive inadequate support from healthcare and public services. CWMT or similar cognitive interventions could, in fact, become a first-line intervention in Saudi Arabia, upon further validation and confirmation of its benefits for children with ADHD.

Institutional Review Board Statement

The study was conducted according to the guidelines of the of the Unit of Biomedical Ethics at King Abdelaziz University (ID number_388-19 /21 May 2019).

Data Availability Statement

Data and additional information about the study will be available upon request to the corresponding author.

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Conflicts of Interest

No potential competing interest was reported by the authors.

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Appendix A. Survey used to collect parents' feedback after the end of the program

1. How satisfied were you with the training program?

1	2	3	4	5
Not satisfied at all	Slightly satisfied	Moderately satisfied	Very satisfied	Extremely satisfied

2. How well did the training program address your problems?

1	2	3	4	5
Not well at all	Slightly well	Moderately well	Very well	Extremely well

3. How likely are you to continue using the techniques from the program?

1	2	3	4	5
Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely

4. How likely are you to recommend others to use the program?

1	2	3	4	5
Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely

5. [Open-ended] Did you encounter any problems or issues during the training program?

6. [Open-ended] Do you have any feedback about the training program?

Tables

Table 1. Demographic and clinical characteristics of the sample.

	Full Sample (n= 29)	**Compliant children (n= 18; 62 %)**	**Non-compliant children (n= 11; 38 %)**	
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*p-value*
Age	10.56 ± 2.62	11.32 ± 2.37	9.33 ± 2.64	0.112 [a]
VADRS Total Scores				
Inattention	2.01 ± 0.63	1.91 ± 0.58	2.16 ± 0.71	0.204 [a]
Hyperactivity/Impulsivity	2.05 ± 0.73	1.88 ± 0.78	2.31 ± 0.59	0.122 [a]
Oppositional Defiant Disorder	1.53 ± 0.70	1.47 ± 0.64	1.62 ± 0.81	0.521 [a]
Conduct Disorder	0.37 ± 0.62	0.18 ± 0.16	0.68 ± 0.92	0.340 [a]
Anxiety/Depression	0.95 ± 0.69	0.82 ± 0.65	1.16 ± 0.74	0.256 [a]
	N	*N (%)*	*N (%)*	
Sex				
Male	25	14 (56%)	11 (44%)	0.129 [b]
Female	4	4 (100%)	0	
ADHD subtype				
Inattentive	6	5 (83%)	1 (17%)	0.601 [b]
Hyperactive/Impulsive	3	2 (67%)	1 (33%)	
Combined	20	11 (55%)	9 (45%)	

Clinical care				
None	22	15 (68%)	7 (32%)	0.216 [b]
Pharmacological intervention	4	2 (50%)	2 (5%)	
Behavioral intervention	1	1 (100%)	0	
Combined intervention	2	0	2 (100%)	
Co-occurring conditions				
Autism	3	1 (33%)	2 (67%)	0.316 [b]
ODD	4	2 (50%)	2 (50%)	0.493 [b]
CD	2	1 (50%)	1 (50%)	0.623 [b]
Anxiety/depression	2	1 (50%)	1 (50%)	0.623 [b]
Learning disabilities	2	2 (100%)	0	0.377 [b]
Education				
Regular education	18	12 (67%)	6 (33%)	0.396 [b]
Special education	11	6 (55%)	5 (45%)	

[a] Mann-Whitney U test. [b] Fisher's Exact test

Table 2. Parental education level, occupation and economic background.

	Full Sample	Compliant children	Non-compliant children	
	N	*N* (%)	*N* (%)	*p value*
Parental education level				
High School or less	13	10 (77%)	3 (23%)	0.308 [a]
Bachelor/ diploma	9	4 (44%)	5 (56%)	
Master or PhD	7	4 (57%)	3 (43%)	
Parental occupation				
Employed	19	10 (53%)	9 (47%)	0.380 [a]
Unemployed	8	6 (75%)	2 (25%)	
Student	2	2 (100%)	0	
Type of house				
Traditional	4	3 (75%)	1 (25%)	0.449 [a]
Villa	6	5 (83%)	1 (17%)	
A floor	19	10 (53%)	9 (47%)	
Rented	13	8 (62%)	5 (38%)	0.628[a]
Owned	16	10 (63%)	6 (37%)	
Cars owned				
No car	2	0	2 (100%)	0.226[a]
One car	17	12 (71%)	5 (29%)	
Two or more cars	10	6 (60%)	4 (40%)	
Other ownerships				
Phone	29	18 (62%)	11 (38%)	N/A

TV	29	18 (62%)	11 (38%)	N/A
PC	25	16 (64%)	9 (36%)	0.493[a]
Internet	28	18 (64%)	10 (36%)	0.379[a]
Library access (within the local area)	9	5 (56%)	4 (44%)	0.466[a]
Satellite TV	24	15 (63%)	9 (37%)	0.644[a]
Videogames	13	9 (69%)	4 (31%)	0.372[a]

[a] Fisher's Exact test

Table 3. Time spent on training for ‘compliant’ and ‘non-compliant’ participants

	Full Sample	**Compliant children**	**Non-compliant children**	
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*p-value*
Average Active Training time (per session)	39 ± 6	38 ± 5	40 ± 7	0.261 [a]
Average Pause time (per session)	12 ± 13	12 ± 16	12 ± 8	0.461 [a]
Average Overall Training time (per session)	51 ± 16	50 ± 17	52 ± 12	0.338 [a]
Total Active Training time (full program)	784 ± 284	944 ± 124	425 ± 192	<0.001 [a, *]
Total Pause time (full program)	252 ± 335	305 ± 389	133 ± 101	0.054 [a]
Total Overall Training time (full program)	1037 ± 503	1249 ± 431	558 ± 274	<0.001 [a, *]

[a] Mann-Whitney U test.
M and SD are reported in minutes
*p<0.05

Table 4. Cogmed Start Index, Max Index and Improvement Index for ‘compliant’ and ‘non-compliant’ participants

	Full Sample	**Compliant children**	**Non-compliant children**	
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*p-value*
Cogmed Start Index	66.50 ± 12.11	67.06 ± 12.74	65.25 ± 11.26	0.724 [a]
Cogmed Max Index	100.00 ± 23.12	105.00 ± 25.27	88.75 ± 12.26	0.030 [a,*]
Cogmed Improvement Index	33.50 ± 20.26	37.94 ± 21.34	23.50 ± 13.95	0.041 [a]

[a] Mann-Whitney U test.
*p<0.05

Table 5. Summary of Cogmed Progress Indicators (CPIs) for working memory, following instructions and math skills in 'compliant' and 'non-compliant' children

	Full Sample	**Compliant children**	**Non-compliant children**	
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*p-value*
CPI Working Memory				
Start Index	2.81 ± 1.24	3.01 ± 1.02	2.34 ± 1.62	0.567 [a]
Max Index	5.17 ± 1.85	6.03 ± 1.12	3.24 ± 1.72	<0.001 [a]
Improvement Index	1.00 ± 0.96	1.21 ± 0.79	0.53 ± 1.18	0.005 [a]
CPI Following Instructions				
Start Index	1.41 ± 1.04	1.69 ± 0.98	0.77 ± 0.92	0.041 [a]
Max Index	3.50 ± 1.55	4.29 ± 0.72	1.70 ± 1.41	<0.001 [a]
Improvement Index	1.34 ± 1.22	1.67 ± 1.19	0.60 ± 1.00	0.013 [a]
CPI Math				
Start Index	6.68 ± 4.64	7.61 ± 4.85	4.59 ± 3.55	0.115 [a]
Max Index	14.95 ± 7.80	18.75 ± 5.38	6.43 ± 5.17	<0.001 [a]
Improvement Index	3.01 ± 7.42	4.19 ± 8.80	0.49 ± 1.04	0.001 [a]

[a] Mann-Whitney U test
*p<0.05