Qbtech

Clinical documentation for QbTest and QbCheck

1. Introduction

QbTest and QbCheck are objective tests that can be used in the assessment of ADHD and for the evaluation of different treatments in patients with ADHD. Both tests involve motion tracking systems and computerized tasks that require continuous attention and impulse control. As a result, the tests provide data on all core signs of ADHD, that is, hyperactivity, impulsivity, and inattention.

The tests can be used in children (6-12 years) and in adolescents/adults (12-60 years). The computerized tasks differ in cognitive demand between the child version (go-no go paradigm) and the adolescent/adult version (unconditional identical pair paradigm). This document describes clinical studies supporting the use of QbTest/QbCheck in the assessment of ADHD and for treatment interventions in patients with ADHD. More than 50 studies using QbTest/QbCheck have been published, of which the majority are peer-reviewed independent publications.

QbTest is indicated for use in the assessment of ADHD and in the evaluation of treatment interventions in patients with ADHD (Hall et al., 2023; National Institute for Health and Care Excellence, 2023). The documentation is based on studies with QbTest but since QbCheck is substantially equivalent to QbTest with the main difference that QbCheck can be performed online using a web-camera, the below documentation can also be considered valid for QbCheck.

2. Validity

The test is not designed to be a stand-alone tool for the diagnosis of ADHD. Rather, it should be seen as a key component in the assessment together with other clinical data, such as structured clinical interviews and subjective information from validated rating scales. It is, however, important that QbTest can differentiate patients with ADHD from normative individuals.

To test the accuracy of QbTest and check the validity of the device, Edebol et al. examined the discriminant validity of the test in a sample of 55 adult patients with ADHD (mean age 33 years) and 202 normative participants (mean age 31 years). A composite measure of ADHD based on three cardinal symptom variables from the test representing hyperactivity, inattention, and impulsivity yielded 86% sensitivity and 83% specificity (Edebol et al., 2013a).

One study evaluated if hyperactivity measured during the test not only was present in children but also in adults with ADHD. 20 adult patients diagnosed with ADHD (mean age 37.3 years) and 20 healthy controls (mean age 37.5 years) were included and QbTest results were compared (Lis et al., 2010). The study showed that not only inattention but also hyperactivity, measured by QbTest, was statistically significantly more prominent in ADHD than in controls, increased with test duration, and only covaried with cognitive performance in the subjects with ADHD. There was a correlation between self-rated hyperactivity (Adult ADHD Self Reporting Scale (ASRS)) and objectively measured hyperactivity in the normal control group ($r=0.56$), but not in the ADHD group ($r=0.07$), indicating that the group with ADHD had difficulties assessing their symptom (Lis et al., 2010).

An exploratory factor analysis was performed in 828 children (age 6-11 years) using QbTest, resulting in a three-factor model representing hyperactivity, inattention, and impulsivity respectively. Hyperactivity explained the largest amount of variance and the two other factors, inattention and impulsivity, each explained additional unique parts of variance. Convergent validity with the Conner's teacher rating scales was found for the hyperactivity factor but not for the inattention and impulsivity factors. It was hypothesized that teachers are better able to detect externalizing behavior (i.e., hyperactivity) that is highly visible in classroom situations than internalizing behavior (i.e.,

inattention), that normally does not disturb classroom proceedings (Reh et al., 2015). In addition, the three-factorial structure (hyperactivity, inattention, impulsivity) was also verified in a confirmatory factor analysis using QbTest (n=773, age >12 years) (Hirsch & Christiansen, 2017).

Hyperactivity, inattention, and impulsivity were evaluated in 45 children with ADHD (mean age 9.2 years), 22 non-affected siblings (mean age 11.2 years), and 45 unrelated controls (mean age 8.9 years) with no family history of ADHD. The ADHD children showed the greatest impairments on all three QbTest factors, followed by their non-affected siblings, with control children showing the lowest scores. Group differences between the non-affected siblings and controls were only statistically significant for the motion tracking-based hyperactivity factor, indicating that hyperactivity assessed by QbTest may be a useful intermediate phenotype in ADHD. It was concluded that since the QbTest factors are based on the neuropsychological level of the disorder they may represent a marker for ADHD that could ultimately help to improve phenotype definition (Reh et al., 2014).

The discriminant validity for the adult version of the test in different psychiatric populations has been further evaluated. In one study (Söderström et al., 2014), a naturalistic sample of 61 clinic-referred patients with suspected ADHD, of which 41 patients (mean age 32 years) met the criteria for ADHD and only 20 did not (mean age 30 years), were used to evaluate the discriminant validity of the three QbTest factors (hyperactivity, impulsivity, and inattention). The impulsivity and inattention factors showed high stand-alone specificity (80 and 100% respectively) but low stand-alone sensitivity (59% and 36% respectively), whilst the hyperactivity factor showed moderate stand-alone sensitivity and specificity (68 and 65% respectively). Interestingly, the self-rating scales (ASRS and Current Symptom Scale (CSS)) showed the inversed results, with high sensitivity (90% and 85% respectively) and low specificity (35% and 40% respectively). A stepwise discriminant function analysis showed that a combination of the Hyperactivity and Inattention factors yielded 72.1% correct classification of the individuals with a sensitivity of 87.8% and a specificity of 40.0%. The low specificity could be explained by the fact that the patients were referred by psychiatric clinics to a specialized ADHD clinic due to suspected ADHD and therefore several of the patients who did not meet the diagnostic criteria (control group) had ADHD-like symptoms (Söderström et al., 2014).

In a larger study, a weighted symptom score was developed by operationalizing the three cardinal symptom variables from QbTest representing hyperactivity, inattention, and impulsivity to yield a summary score between 0 and 100, where 0 indicate maximal amount of ADHD symptoms and 100 indicate complete absence of ADHD symptoms. The respective scores for normative individuals (n=179, mean age 31.4 years), patients with disconfirmed ADHD diagnosis (n=29, mean age 35.2 years), patients with Bipolar II/Borderline Personality disorder (n = 45, mean age 40.1 years) and patients with ADHD (n=53, mean age 35.9 years) were 71, 40, 46, and 18. The ADHD group scored statistically significantly lower than all other groups and the normative group scored statistically significantly higher than all other groups, indicating that a summary score from the test in an adult population not only can differentiate ADHD from norm but also from other clinical groups (Edebol et al., 2012).

In an adult clinical population under assessment for ADHD (n=108, mean age 30 years) Petterson et al. evaluated which variables commonly used in different objective tests during assessment best predicted final clinical diagnosis. The study showed that the variables with best validity were the cardinal variables for hyperactivity (QbActivity) and inattention (QbInattention) from QbTest, and the variable commission errors used in Conner's CPT II. When these

variables were used in combination with DIVA (Diagnostic Interview for ADHD in adults), the specificity of the diagnosis was increased by 10% (Pettersson et al., 2018).

The gradual effect of combining QbTest with subjective measures was studied in 60 children (mean age 9 years) and 76 adults (mean age 33 years). The data showed that QbTest had a stand-alone accuracy of 79% in adults and 78% in children. When combined with subjective measures, the accuracy increased to 89.5% in adults and 86.7% in children (Emser et al., 2018).

In a naturalistic study (tertiary outpatient clinic specialized in assessment and treatment of ADHD) 67 adults (mean age 33 years) with ADHD explored whether QbTest performance at baseline predicted future attentional performance with subjective symptom ratings and/or clinicians' reports at follow-up 4 years later. At the 4-year follow-up (n=41), fewer patients scored above the QbTest cutoff, and their symptom self-ratings had improved. The QbInattention score at baseline correlated significantly with follow-up self-ratings (ASRS and Brown Attention-Deficit Disorder Scale (BADDS)) (r=0.49) (Nylander et al., 2022).

Oades et al. assessed if there could be any correlation on biochemical brain markers and objective measurements for ADHD. 21 children with ADHD (mean age 8.9 years) and 21 normative children (mean age 11.0 years) were included. Group comparisons on QbTest performance revealed statistically significant differences between the ADHD and normative group. In addition, several QbTest variables were associated with different biochemical brain markers in the ADHD group (Oades et al., 2010).

QbTest's ability to differentiate ADHD from Autism Spectrum Disorder (ASD) in an adult population (n=37, age 18-60 years) was examined by Groom et al. (Groom et al., 2016). In similarity with the study performed in children above, QbActivity ($p < 0.001$) and QbInattention ($p < 0.001$) were the most effective variables in differentiating ADHD from ASD, but also the cardinal variable for impulsivity (QbImpulsivity) showed a statistically significant effect in this respect ($p < 0.01$). By adding the information from QbTest to the results from the subjective rating scales, correct classification could be increased from 84% to 94% (ADHD) and from 76% to 84% (ASD).

One study performed in older adults (age 55-79 years) with ADHD (n=97) and controls (n=112) showed that QbTest had a stand-alone accuracy of 70%, which increased to 91 % when combined with self-reports of ADHD severity (Bijlenga et al., 2019).

A comprehensive systematic review analyzing the weighted average of sensitivity and specificity of QbTest has been published (Gustafsson & Hansen, 2023b). Ten studies with a control arm design and robust sample size were identified for this purpose (Adamou et al., 2022; Bijlenga et al., 2019; Brunkhorst-Kanaan et al., 2020; Edebol et al., 2012, 2013a; Emser et al., 2018; Groom et al., 2016; Hult et al., 2018; Pettersson et al., 2018; Söderström et al., 2014). All ten studies assessed the ability of QbTest to discriminate between an ADHD population and one or more control populations. QbTest was used as intended, but the study designs did not capture the value of adding QbTest in the diagnostic process or blinding the clinicians of the QbTest results in the control arm. Weighted analyses made with all ten controlled studies pooled together, yielded a robust sensitivity of 0.84 and a specificity of 0.84, representing QbTest's ability to discriminate across a mixed population of normative and differential diagnosed individuals. QbTest performed well with a weighted average sensitivity of 0.89 and specificity of 0.87 across four studies with normative controls. Analysis was also conducted on five studies with a sufficient sample size, defined as over 50 participants in each comparative arm, resulting in a strong sensitivity of 0.83 and a specificity of 0.86.

Another meta-analysis on QbTest by Bellato et al. (2023) (Bellato et al., 2023) on nine pooled studies (Adamou et al., 2022; Bijlenga et al., 2019; Edebol et al., 2011, 2013a; Emser et al., 2018; Groom et al., 2016; Hollis et al., 2018; Johansson et al., 2021; Ulberstad et al., 2020), found an overall sensitivity of 0.78 and specificity 0.70 , which slightly differs versus the findings of the ten pooled studies by Gustafsson and Hansen above (2023b) (Gustafsson & Hansen, 2023b). Bellato et al. (2023) used a different analytical method (random-effects bivariate model) based on area under the curve analysis and included studies with any design investigating the clinical utility of QbTest. It should be noted that Gustafsson and Hansen (2023b) analyses were based on weighted averages analysis, which gives more value to those items in the average that occur relatively more in contrast to a simple average which does not, and that the Gustafsson and Hansen (2023b) review had a more stringent inclusion/exclusion criteria than Bellato et al. (2023). Thus, different studies were included between these two reviews in the diagnostic evaluation of QbTest. Finally, the reported data from the Gustafsson and Hansen (2023b) review were based on composite Q-scores from the QbTest, the most comprehensive composite available from QbTest, and rating scales to give the most relevant sensitivity and specificity from a clinical standpoint when QbTest was used as an adjunct to support full assessment (Gustafsson & Hansen, 2023b). This contrasts with Bellato et al. (2023) who based their findings when QbTest was used as a standalone tool, in contravention to its intended use (Bellato et al., 2023).

In both the above review publications, only one study (Hollis et al., 2018) investigated QbTest in line with its intended use, as an aid in the clinical assessment of ADHD. Nevertheless, QbTest, when used as intended, reduces the time from assessment to final decision, and increases the number of diagnostic decisions made as well as the clinicians' confidence in their decision-making, without compromising diagnostic accuracy.

Moreover, a high test–retest reliability of QbTest between two baselines on each trial day was found in an expectancy effects assessment randomized study after one-single dose of methylphenidate and after one-single dose of placebo (n=40, mean age 34 years) (Löhman et al., 2023).

3. Diagnostic Support Tool

One randomized controlled study which had a study design that concisely assessed the impact of adding QbTest to the clinical workflow in ADHD assessment has been identified (Hollis et al., 2018). In this study (n=250, aged 6-17 years), all patients performed QbTest, but patients and clinicians were randomized to either receive the QbTest results immediately (QbOpen group) or the QbTest was withheld (QbBlind group). Clinicians with access to QbTest were 44% more likely to make a diagnostic decision within the 6-month follow-up period (p=0.003). At 6 months, 76% of the patients in the QbTest group had received a diagnosis compared to 60% in the control group (p=0.003). QbTest reduced appointment length by 15% (p=0.001). Clinicians in the QbTest group were twice as likely to exclude a diagnose of ADHD and were also more confident in their diagnostic decision. These results were achieved without compromising the diagnostic accuracy (Hollis et al., 2018). Furthermore, semi-structured interviews and a survey assessing the experience of the QbTest were conducted in a sub-set of clinicians and families participating in the study described above by Hollis et al. (secondary analysis). The QbTest was found to facilitate communication between clinicians, families and schools and was also considered useful both among clinicians and families, reassuring the feasibility of the test (Hall et al., 2017).

In one pragmatic randomized controlled trial utilizing QbTest, the aim was to assess the feasibility of QbTest for young people in prison (n=60, aged 15-18 years). Participants were randomized to QbTest plus usual care or just usual care for 6 months. Participants, including clinical staff, were mostly supportive of the study and QbTest; however, some young people found QbTest hard and there were issues with implementation of the ADHD care pathway, though this did not affect the participants to complete the test. There were no serious adverse events secondary to the study or intervention and no one was withdrawn from the study due to an adverse event (Chitsabesan et al., 2022).

In one study the aim was to evaluate if adding QbTest in the clinical assessment of ADHD could impact clinical accuracy. 46 children (mean age 9 years) were diagnosed without using QbTest and 62 children (mean age 10.5 years) were diagnosed with QbTest as part of the diagnostic procedure. The study showed that QbTest significantly increased the diagnostic accuracy ($p= 0.0035$) measured by subsequent rates of revised diagnosis over a 12-month period. It was also concluded that greater symptom specification, with the use of QbTest measurements, clinical decisions remained more consistent and were less likely to be revised over 1 year (Vogt & Shameli, 2011).

4. Treatment response

Several studies have been performed in children, adolescents and adults for which QbTest has been used to monitor medication treatment response.

Wehmeier et al. evaluated the effect of atomoxetine by means of QbTest and clinical rating scales. 125 children with ADHD, aged 6-12 years (mean age 9 years), were randomized to treatment with atomoxetine or placebo and followed for 8 weeks (study data were published as four separate articles, Wehmeier et al., 2011, 2012, 2014, 2015). The study showed statistically significant effects after 8 weeks of treatment for all QbTest variables ($p<0.001$). The observed effects were also confirmed by the validated clinical rating scales used in the study. The highest correlations for treatment effects between the clinical rating scales (for example ADHD-Rating Scale (ADHD-RS)) and QbTest results were around 0.50-0.60 (Wehmeier et al., 2012). Reduced ADHD symptom severity could also be measured by QbTest regardless of whether patients (n=125, same population described above) were pre-treated with or without stimulant medication (Wehmeier et al., 2014). Furthermore, a secondary analysis on the same population (n=125) showed that treatment effect of atomoxetine on hyperactivity appears to be more pronounced in the subgroup of patients with comorbid oppositional defiant disorder or conduct disorder than in the subgroup without one of these comorbidities (Wehmeier et al., 2015). Another article by the same author (based on same population as described above) showed that by using QbTest, not only treatment effect over time in children 6-12 years (n=105) could be seen, but also circadian pattern of treatment response across the day could be measured (Wehmeier et al., 2011).

In a group of 36 children with ADHD (aged 8-12 years), the effect of immediate-release and long-acting methylphenidate formulations was examined (Günther et al., 2012). All included children performed a QbTest four times during the same day within 8 hours, and circadian fluctuations of treatment response could be detected by using QbTest (Günther et al., 2012).

One study investigated response to methylphenidate, 44 children and adolescents (aged 7-18 years) with confirmed hyperkinetic disorders performed a QbTest before and after a test dose of methylphenidate. A robust treatment response was confirmed in 84% of the patients ($p<0.05$), 7% demonstrated a partial response and 9% were determined as non-responders due to deteriorating activity measures together with no improvement in attention and impulse control measures. It was

stated that QbTest is effective in the early identification of treatment response to stimulant medication (Vogt & Williams, 2011).

Clinical gains from including both dextroamphetamine and methylphenidate in stimulant trials have been investigated. QbTest was performed in 36 medication-naïve children aged 9-14 years diagnosed with ADHD in a cross-over design (duration of treatment was 2 weeks). High effect sizes, measured by a composite QbTest variable, were shown for both methylphenidate and dextroamphetamine. Likewise, the observed treatment effects using QbTest were verified by clinical rating scales (Ramtvedt et al., 2013).

The effect of methylphenidate in 23 adult prisoners (mean age 34.4 years) with ADHD and other coexisting disorders has been studied, in which QbTest was performed after 16 and 52 weeks. The study showed statistically significant effects after 16 weeks of treatment ($p<0.05$) for all QbTest variables and further improvements were observed in some QbTest variables after 52 weeks of treatment ($p<0.05$). The observed effects using QbTest were correlated by clinical rating scales (Ginsberg et al., 2012).

63 adult patients with ADHD (mean age 35.2 years) given a single dose of methylphenidate (mean dose 13.7 mg) showed a statistically significant ($p<0.001$) decrease in symptom levels (2-3 hours after intake of stimulant) measured by QbTest for all cardinal symptoms and a weighted symptom score. In a second part of the study, 10 patients were subjected to methylphenidate dose titration up to 72 mg for 3 months of treatment. The weighted symptom score derived from QbTest, but not the different rating scales used, was able to identify symptom level reduction between baseline and all investigated dose levels (Edebol et al., 2013b).

Bijlenga et al. compared response to medical treatment with methylphenidate or dexamphetamine in patients (mean age 31 years, n=82) with ADHD measured by objective QbTest or a subjective ADHD rating scale (ADHD-RS). A decrease in total Q-score score was found after 4 weeks of stimulant treatment compared to baseline ($p<0.001$). The study showed statistically significant ($p< 0.01$) but low ($r=0.33$) correlations in total score changes for the two methods. The QbTest Total score was calculated as the mean value of the three cardinal parameters; QbActivity, QbImpulsivity, and QbInattention. The authors suggested that subjectively and objectively measured symptoms may be different ADHD-related constructs. QbTest was more sensitive to medication effects and could objectify an improvement in 54% of patients who did not subjectively report an improvement. High baseline QbTest scores predicted large treatment effects measured both with objective (QbTest) and subjective (ADHD-RS) methods (Bijlenga et al., 2015).

In a large cohort of children and adolescents (n=364, mean age 13.6 years) QbTest was used before and after (up to three hours) single administration of methylphenidate. The QbTest inattention and motor activity parameters improved markedly after a single dose of methylphenidate, while less so for impulsivity (Knez et al., 2021).

In a study by Cedergren et al., the effectiveness of ADHD medications (methylphenidate, lisdexamfetamine, guanfacine or atomoxetine) in children 6-18 years (n=78) was studied for one year. QbTest results demonstrated reductions in symptoms on all cardinal parameters between baseline and after 1 month ($p<0.01$) as well as 12 months ($p<0.01$) of treatment with stimulants. There was a weak but significant correlation between the total change scores of QbTest and ADHD-RS from baseline to 1 month ($r=0.28$, $p<0.05$) but not after 12 months of treatment, though there was a robust significant reduction in symptoms assessed by QbTest from baseline to endpoint (Cedergren et al., 2022).

Martin-Key et al. evaluated the clinical utility of the combined use of objective (QbTest) and subjective symptom measures of ADHD before and after pharmacological treatment with methylphenidate, amphetamine, lisdexamphetamine ordextroamphetamine-amphetamine for 6 months (mean age 36 years, n=71). Mean total QbTest Q-score was decreased within 2-5 weeks of treatment ($p<0.001$) and further declined after 6 months of treatment compared to baseline ($p<0.001$), for which 86% of the patients showed an improvement (Martin-Key et al., 2022).

Another study investigated the effect of a cannabinoid medication in patients diagnosed with ADHD in a randomized placebo-controlled study for (n=15 in each group, mean age 37 and 39 years) for a duration of 6 weeks. An estimated difference of total Q-score between active and placebo did not reach statistical significance ($p=0.16$). Along with that, it was concluded that QbTest performance was not impaired following cannabinoid use (Cooper et al., 2017).

A retrospective study investigated the effect of single dose of methylphenidate in children and adolescents (6-18 years, n=343) with ASD (autism spectrum disorder) alone, ASD plus ADHD, and ADHD alone (Stevanovic et al., 2022). Four hours after administration of methylphenidate, scores for QbActivity and QbImpulsivity decreased similarly in the ASD plus ADHD group and the ADHD alone group ($p<0.01$). QbImpulsivity increased in the ASD alone group ($p<0.05$), while QbInattention scores decreased similarly in all groups after methylphenidate intake ($p<0.01$).

A systematic review publication (Gustafsson & Hansen, 2023a) analyzed 15 clinical studies (Bijlenga et al., 2015; Cedergren et al., 2022; Cooper et al., 2017; Edebol et al., 2013b; Ginsberg et al., 2012; Günther et al., 2012; Knez et al., 2021; Martin-Key et al., 2022; Nylander et al., 2022; Ramtvedt et al., 2013; Stevanovic et al., 2022; Vogt & Williams, 2011; Wehmeier et al., 2011, 2012) for which QbTest was used in monitoring medication treatment response in ADHD. Changes in QbTest data (Q-scores, effect size or improvement/deterioration of QbTest variables) were analyzed. A clinical decrease in QbTest Q-scores was found in the majority of studies when treated with any type of ADHD medication in therapeutic doses, both in comparison to placebo and compared from baseline to endpoint treatment. This pattern was seen both in short-term (over course of a day) and in long-term (≥ one year) studies. Thus, this systematic review publication concluded that there is clear evidence that QbTest can distinguish medication treatment effect within hours of pharmacological titration and can also be used as an aid for medication evaluation of long-term treatment of ADHD.

5. Other findings and implications

A few publications have shown less differentiation of ADHD from clinical controls with the device (none of the studies used QbTest according to its intended purpose).

Johansson et al. evaluated 340 participants recruited from a twin-register of 15-year-old individuals identified through a telephone screening with high occurrence of neurodevelopment disorders. Of these, 89 individuals were later diagnosed with ADHD using K-SADS (Kiddie Schedule for Affective Disorders and Schizophrenia). QbTest showed poor validity in differentiating ADHD from clinical controls in this group (Johansson et al., 2021). A confounding issue could be that individuals did not contact the health care teams themselves; they were contacted by clinicians through a twin-register, which may have resulted in an overdiagnosis of ADHD in the selected population (Johansson et al., 2021).

One study evaluated the diagnostic validity of QbTest in 80 children (median age 12.5 years) with ADHD and 38 clinical controls (median age 11.2 years), in which QbTest showed inferior validity (Tallberg et al., 2019). However, in both these mentioned studies (Johansson et al. and

Tallberg et al.), the ADHD groups showed surprisingly normal QbTest scores which were more similar to the QbTest scores in individuals without ADHD reported in the other studies. This might be a confounding factor of the low classification accuracy in these studies.

Bronkhorst-Kanaan et al. examined the ecological validity of the QbTest in the diagnostic process in an outpatient clinic between adult patients with ADHD (n=94) or with disconfirmed ADHD (n=20) (mean age around 35 years in both groups). The study showed that the QbTest was not able to discriminate between ADHD patients and non-ADHD patients in an outpatient clinic. Yet, QbActivity was the only parameter to significantly distinguish ADHD from the control (Brunkhorst-Kanaan et al., 2020).

A retrospective study examined the structure and diagnostic ability of the QbTest in children and adolescents aged 6-18 years (n=1274, period covered year 2004–2017 in Sweden). The diagnostic accuracy of QbTest was found to be modest in pediatric ADHD (Stevanovic et al., 2023). It should be mentioned that the number of subjects in the clinical control group was extremely low (3%) compared to the total population studied, and approximately two thirds of the participants had comorbid disorders in the ADHD group (Stevanovic et al., 2023).

One study evaluated the QbTest as an objective measure of ADHD symptoms in 69 adults (mean age 33 years) in a specialist clinic for possible diagnosis of ADHD (Adamou et al., 2022). Scores from the QbTest failed to differentiate between patients diagnosed with ADHD and those who did not receive a diagnosis after full clinical assessment. The limitations discussed of the study highlight that it was only one single center and a larger sample size would have been valuable (Adamou et al., 2022). Another limitation is that the non-ADHD group had atypical scores on the QbTest, which would suggest that the non-ADHD group may actually have belonged to the ADHD population.

6. Clinical utility

The clinical utility of QbTest has also been examined in a couple of studies.

Martin-Key et al. investigated the clinical utility of the combined use of objective and subjective measures of before and after pharmacological treatment in 71 adults with ADHD (mean age 36 years). By using objective (QbTest) and subjective measures of ADHD-related symptoms during initiation and follow-up of pharmacological treatment, significant improvements in quality of life were achieved after 6 months. A correlation $r=0.39$, $p<0.03$ was found between QbTotal (score) and Quality of Life (Adult ADHD Quality of Life Questionnaire; AAQoL score). The findings suggested that the QbTest captures a measurable component of the condition and that improvements on the test are related to real-life subjective improvements in daily functioning (Martin-Key et al., 2022).

A pilot study examined the impact of the introduction of the QbTest in the Child and Adolescent Mental Health Services in Ireland. Thematic analysis of focus group transcripts highlighted that clinicians considered the QbTest a valued addition to ADHD assessment as it was efficient, objective and clear. Survey data suggested that clinicians, service users and their families found the QbTest helpful and acceptable (Pellegrini et al., 2020). Thus, QbTest may be considered to have clinical value when it provides information which can be used for clinical management decisions of ADHD.

Health economic data from the Hollis et al. (2018) child and adolescent study showed small cost-savings for the health service and improved outcomes, though the overall health economic impact of QbTest was considered as neutral. The health economic analyses were however compromised by the limited study period (6-month time frame) and therefore

longer-term costs associated with cases still waiting for their diagnosis (24% in the QbTest group and 40% in the control group) could not be accounted for. Nevertheless, the final conclusion of the study regarding health economy was that QbTest may increase patient throughput and reduce waiting times without significant increases overall health system costs (Hollis et al., 2018).

In an audit study performed at three community pediatric mental health centers in the UK, an economic evaluation and return on investment analysis was performed (1250 children underwent a QbTest across all three Trusts). The audit showed that, after the implementation of QbTest, the number of days to reach a clinical decision was reduced from 161-453 days (5-15 months) to 15-252 days (2 weeks to 8.5 months). In addition, the average days from assessment to commencing medical treatment decreased from 42-179 days to 15-96 days. Based on the above mean estimates, these effects could be translated into cost reductions ranging from 9-39% (Humphreys & Sitton-Kent, 2018).

7. Other attributes of using QbTest

In a feasibility randomized controlled trial (medication monitoring) in children (n=44, age 6-15 years), participants were randomized into one of two arms: experimental (QbTest protocol) where participants completed a QbTest at baseline and two follow-up (2-4 weeks and 8–10 weeks later) QbTest on medication (methylphenidate or lisdexamfetamine). The control group received treatment as usual, including at least two follow-up consultations. Interview data indicated that the objectivity of the QbTest was appreciated by clinicians and parents alike in comparison to informant measures that are traditionally used to monitor medication. Clinicians also commented that it was not feasible to use QbTest in medication management for all cases due to the additional clinic time and resources required, when balanced against the additional information that QbTest gives; for more simple cases, it may be sufficient to monitor medication using established clinical methods. However, there was a perceived value in using QbTest for more complex patients, which includes comorbidities, and any examples where there was contention about treatment approaches, for which case QbTest was considered particularly helpful (Williams et al., 2021).

In a descriptive case study (including several cases in adolescents) using QbTest, Vogt (2017) alluded that the effect of difficulties in sustaining posture during the tracking of motor activity for motion analysis is significant, resulting in elevated activity scores. Good ability to sustain posture, however, seems to mitigate activity levels. These effects are consistent and appear to occur independent of whether or not deficits in attention or impulse control during QbTest are detected (Vogt, 2017). The same author (Vogt 2021) also elaborated that when conducting a QbTest, clinicians must consider the effect of the laboratory test environment especially on activity levels. Impairment in arousal/alerting functions is accompanied by raised and significantly higher activity levels during the test compared with impairment in response inhibition, where activity levels are on average within the normal range (Vogt, 2021).

Treatment of transcranial direct current stimulation of the prefrontal cortex was investigated in 15 adolescents (age 12-16 years) with ADHD for 20 minutes over five consecutive days. Assessment of QbTest seven days after transcranial treatment showed improvements in QbInattention and QbHyperactivity, but not in QbImpulsivity (Soff et al., 2017).

A preliminary study in adolescents and young adults (age 12-20 years) investigated any associations between QbTest and fractional anisotropy (with MRI) with (n=31) or without ADHD (n=52) (Jones et al., 2023). It was demonstrated that individual differences in activity, inattention and impulsivity on the QbTest are associated with white matter

microstructure in regions subserving attention, motor, and regulatory circuitry.

8. Remote testing by QbCheck

One study examined the psychometric properties of the QbCheck (an online test that uses the build-in web camera found in most computers, thereby enabling easy testing of objective symptoms outside the clinic), to obtain objective measurement of ADHD symptom levels in the home (remote) setting (n=142, age range 12-60 years) (Ulberstad et al., 2020). The results showed that the QbCheck has good test-retest reliability. A good diagnostic validity for discriminating between individuals with ADHD and healthy controls was found with a sensitivity of 0.83 and specificity of 0.80) (Ulberstad et al., 2020). Accordingly, the QbCheck has good concurrent and convergent validity when studying correlations to corresponding variables obtained from the QbTest; it also has good diagnostic validity for discriminating between individuals with ADHD and healthy controls. Thus, QbCheck and QbTest show equivalence of total symptom score.

One investigation evaluated QbCheck administration results when used for remote monitoring of ADHD medication treatment (post hoc analysis (Sanyal et al., 2024). The dataset collected was from clinical routine QbCheck assessments at different clinical sites. QbCheck was administered at baseline, prior to treatment and after ADHD medication treatment began in a population between 7 and 60 years (n=114). The average time between QbCheck assessments (baseline to follow-up) was 66 days (range 1-312 days). A significant improvement ($p<0.001$) from baseline to post-treatment follow-up was seen in all five parameters (microevent, commission error, omission error, reaction time and reaction time variance) which together were associated with a significant reduction in QbCheck Total Symptom Score by 42%. The authors concluded that QbCheck is a useful objective measure that could be incorporated in guiding treatment decisions, remote monitoring of ADHD medication, tracking of ADHD symptom regulation, and optimizing treatment outcomes for those with ADHD.

9. Conclusion

This overview shows that QbTest and QbCheck are valuable tools when used as a support tool in the clinical assessment of ADHD. QbTest has a high validity when used to discriminate ADHD from normative individuals. QbTest can add important clinical information when differentiating ADHD from similar disorders, improve the diagnostic accuracy, and shorten the time to diagnosis. The effectiveness of the test during treatment follow-up has been documented in different patient populations and for different types of therapies. QbTest is able to distinguish medication treatment effect within hours of pharmacological titration and can also be used as an aid for monitoring of long-term treatment of ADHD.

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