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Utilizing Remote Objective ADHD Testing to Monitor Symptom Improvement Following Medication Treatment

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ABSTRACT

QbCheck is a medical device that can be used for remote monitoring to provide health care professionals with objective measurements of hyperactivity, impulsivity, and inattention to aid in the clinical assessment of attention deficit hyperactivity disorder (ADHD). The aim of this investigation was to evaluate QbCheck administration results when used for remote monitoring of ADHD medication treatment. The dataset collected was from clinical routine QbCheck assessments at different clinical sites in the US, and data were stored in a database supplied by QbTech AB, Stockholm, Sweden. QbCheck was administered at baseline, prior to treatment and after ADHD medication treatment began. The sample population age range was between 7 and 60 years, 46% were females, and all subjects were diagnosed with ADHD (N=114). The average time between QbCheck assessments (baseline to follow- up) was 66 days (range 1-312 days). Per standard data collection of the QbCheck, five variables were captured and calculated to indicate measurements of inattention, impulsivity, and hyperactivity. A significant improvement from baseline to post-treatment follow-up was seen in all five parameters (Activity - MicroEventX, Impulsivity – Commission Error, and Attention – Omission Error, Reaction Time & Reaction Time Variance) which were associated with a significant reduction in QbCheck Total Symptom Score by 42.06%. These findings suggest 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.

Keywords

ADHD, Objective testing, QbCheck, Remote testing, Treatment monitoring.

Abbreviations

ADHD: attention-deficit hyperactivity disorder, TSS: Total Symptom Score.

Introduction

Attention-deficit hyperactivity disorder (ADHD) is a prevalent and persistent disorder that emerges early in childhood, with a current prevalence rate of approximately 5 % [1,2]. ADHD is believed to have its onset in early childhood, although it is typically not diagnosed before the school age years and is considered as one of the most common mental health conditions in childhood and adolescence [1,3]. ADHD is characterized by three core symptom domains: inattention, hyperactivity, and impulsivity, for which all domains are of importance to distinguish in any patient for diagnosis and management of ADHD.

Insufficiently treated ADHD negatively affects many consequences such as job instability, drug- and alcohol abuse, social functioning, relations, family functioning, increased healthcare costs [4,5] as well increased mortality rate [6]. Undiagnosed and untreated ADHD is likely to lead to suboptimal outcomes of certain comorbid conditions potentially and thus at a higher cost than if ADHD and comorbid conditions were treated separately [7,8]. Effective monitoring and treatment of ADHD is therefore preferable and would in turn improve not only functionality and quality of life of the individual but would also be a benefit for the family as well as

the society [9].

Patient monitoring is useful for many reasons, most obviously within the context of ongoing treatment as the main tool for treatment titration and preservation, with the goal being to maintain test results within certain limits of a given marker until such a time as treatment can be discontinued or an alternative treatment is needed [10]. The importance of ADHD supervision and therapy can never be underestimated, and due to the large heterogeneity of the disease [11] the optimal approach for monitoring and pharmacological treatment of any individual patient with ADHD regardless of age and sex at birth is yet to be fully characterized and understood [9]. Furthermore, treatment of stimulants in ADHD has increased in the last two decades [12], and approximately 50% of the children (in United States) have been reported being treated with pharmacological medication [12,13]. Thus, evaluation of pharmaceutical treatment effect is important in ADHD, for which subjective and objective measures can indeed be used (with its recognized limitations) in management of ADHD [14].

QbCheck, a test that is substantially equivalent to the QbTest [15,16], is an online test that uses the build-in web camera found in modest computers, to provide health care professionals with objective measurements of hyperactivity, impulsivity and inattention to aid in the clinical assessment of ADHD and monitor treatment response in the home (remote) setting [16]. QbTest is a unique ADHD assessment that uses both a continuous performance test and an infrared camera to capture measurements of hyperactivity, along with inattention and impulsivity [15,17,18]. QbCheck has good concurrent and convergent validity when studying correlations to corresponding variables obtained from QbTest [16] and it also has good diagnostic validity for discriminating between individuals with ADHD and healthy controls [16]. The aim of this post hoc analysis was to evaluate the use of QbCheck in capturing changes in ADHD symptoms pre- and post-pharmaceutical treatment, and whether it can be an effective tool for remote monitoring of ADHD medication treatment.

Methods

QbCheck derives and calculates five parameters (microevents, omission errors, reaction time, reaction time variability and commission errors), which reflect the different markers associated with the three cardinal symptoms of ADHD [16]. Raw scores, Q-scores, and percentiles were calculated for each variable and then adjusted using normative data to correct for age and sex at birth. The Q-scores are reported as standard deviations from the norm population. A Q-score of 1 is equal to 1 standard deviation from the norm population. A Q-score below 1 is considered at a level of normal, non-clinical performance, and a Q score above 1 is considered abnormal. A reduction of Q-score with half a standard deviation (-0.5) is considered to indicate a clinically significant improvement [17,18]. Additionally, a Total Symptom Score (TSS) was calculated based on comparing the normative data with individuals with a clinical diagnosis of ADHD, which has been validated in external validation data set [19]. The TSS is a value from 0 to 100, where the lower the number, the lower the risk of the subject belonging to the clinical group. A TSS above 50 is indicative of a higher risk of the subject belonging to the clinical group.

In this post-hoc analysis, the aim was to evaluate the differences in QbCheck test variables and total scores from subjects' initial assessment and their follow-up visit once ADHD treatment was initiated. Test data was analyzed from subjects seeking their initial evaluation and follow-up treatment. Subjects were considered diagnosed with ADHD if they had 2 QbCheck reports with medication reported on at least one of them. Only patients with no medication recorded on the first QbCheck, defined as the baseline test, AND medication reported on the second QbCheck, defined as the Follow-up were eligible.

The QbCheck data recordings and entered data are stored decoded and anonymously at a database integration server at AWS in Ohio for quality control purposes. No identification of any participant is possible based on this database. Extraction and analysis of QbCheck data from this information collection storage were made for the purpose of this investigation. Statistical analysis was made by using a Paired Student t-test.

Results

A total of 114 subjects from 21 clinics throughout the US identified as having ADHD (mean age = 29.51 years, SD = 11.38, 46% female) had taken a baseline QbCheck without medication usage reported, and a follow-up QbCheck with reported ADHD medication usage. The average time between the baseline assessment and follow-up assessment was 66.47 days (SD = 74.21 days). Five variables are captured and calculated during the QbCheck (MicroEventsX, Commission Errors, Omission Errors, Reaction Time, and Reactive Time Variation). MicroEventsX tracks the subjects' position changes larger than one millimeter since the last MicroEventX, where a larger number indicates a higher degree of activity. Commission errors occur when the subject responds to a non-target stimulus, indicating impulsivity. Omission errors occur when the subject does not respond to a target stimulus. This measure along with Reaction Time and Reaction Time Variation are used to assess inattention. These five quantitative measures are reported as Q-scores and percentiles, which enable comparison to the age and sex at birth adjusted norm group.

A statistically significant decrease in all five Q-scores ($p<0.001$), plus a statistically significant decrease in the TSS ($p<0.001$) were found at the post-treatment follow-up (Table 1). The negative delta value indicates a decrease in Q-scores and TSS from baseline to follow-up, indicating a reduction in that marker for that cardinal symptom of ADHD following medication treatment. A significant decrease in MicroEventX (delta = -0.99, $p<0.001$) indicates a reduction in overall hyperactivity. A significant decrease in Commission Error (delta = -0.71, $p<0.001$) indicates a reduction in overall impulsivity. Significant decreases in Omission Error (delta = -0.94, $p<0.001$), Reaction Time (delta = -0.56, $p<0.001$) and

Reaction Time Variance (delta = -0.99, $p<0.001$) together indicates an overall reduction in inattention (Table 1, Figure 1). When looking at the individual delta values of the TSS, it is interesting to note that there is variability in the degree of improvement from baseline to follow-up post-treatment (Figure 2). This suggests that post-treatment, not every subject improves or reduces their ADHD symptoms uniformly.

Discussion

The aim of this analysis was to evaluate the changes observed in cardinal parameters between the baseline and follow-up assessments post-treatment with ADHD medication. The findings of this investigation build upon a robust body of research indicating the effectiveness of medication in ameliorating ADHD symptoms [20,21]. Specifically, the significant decrease in QbCheck scores post-medication treatment underscores the tangible benefits of pharmacological interventions in improving attention, impulsivity, and hyperactivity symptoms among individuals with ADHD [22].

A notable advantage of utilizing objective assessments like the QbCheck lies in its capacity to facilitate treatment monitoring and dosage titration [23,24]. Continuous assessment of ADHD symptoms would enable clinicians to tailor medication regimens to each patient's specific needs, optimizing therapeutic outcomes while minimizing adverse effects [25]. Figure 2 illustrates the individual changes in QbCheck Total Symptom Scores post

Table 1: QbCheck test results for the five parameters (microevent, commission error, omission error, reaction time and reaction time variance) (in Q-scores) and Total Symptom Score (range 0-100) at Baseline (BL) and Follow-Up (FU).

Parameter	Baseline (n=114)	Follow-up (n=114)	Change from BL to FU	Percent (%) change from BL to FU	Statistical significance of change
MicroEventX	2.53 (1.13)	1.54 (1.23)	-0.99	-39.13%	<0.001
Commission Error	1.63 (1.36)	0.92 (1.14)	-0.71	-43.56%	<0.001
Omission Error	1.62 (1.09)	0.68 (1.23)	-0.94	-58.02%	<0.001
Reaction Time	1.01 (1.25)	0.45 (1.33)	-0.56	-55.45%	<0.001
Reaction Time Variance	1.80 (1.27)	0.81 (1.24)	-0.99	-55.00%	<0.001
Total Symptom Score (range 0-100)	76.79 (25.04)	44.60 (32.42)	-32.3	-42.06%	<0.001

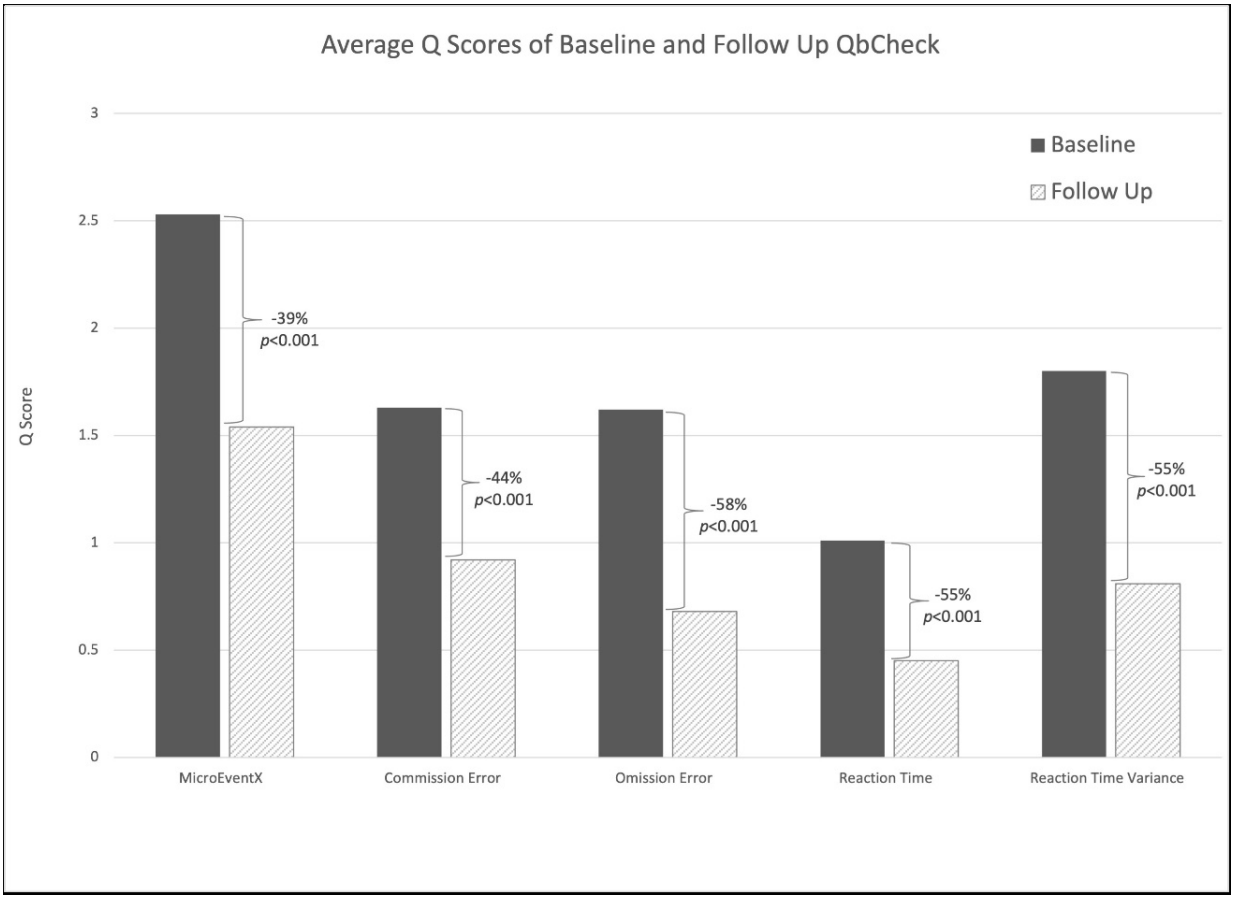

Figure 1: Comparing the average Q scores of each parameter at baseline and post-medication treatment follow-up assessment of QbCheck. The percent change in scores from baseline to follow-up is indicated, along with the significance levels of those changes.

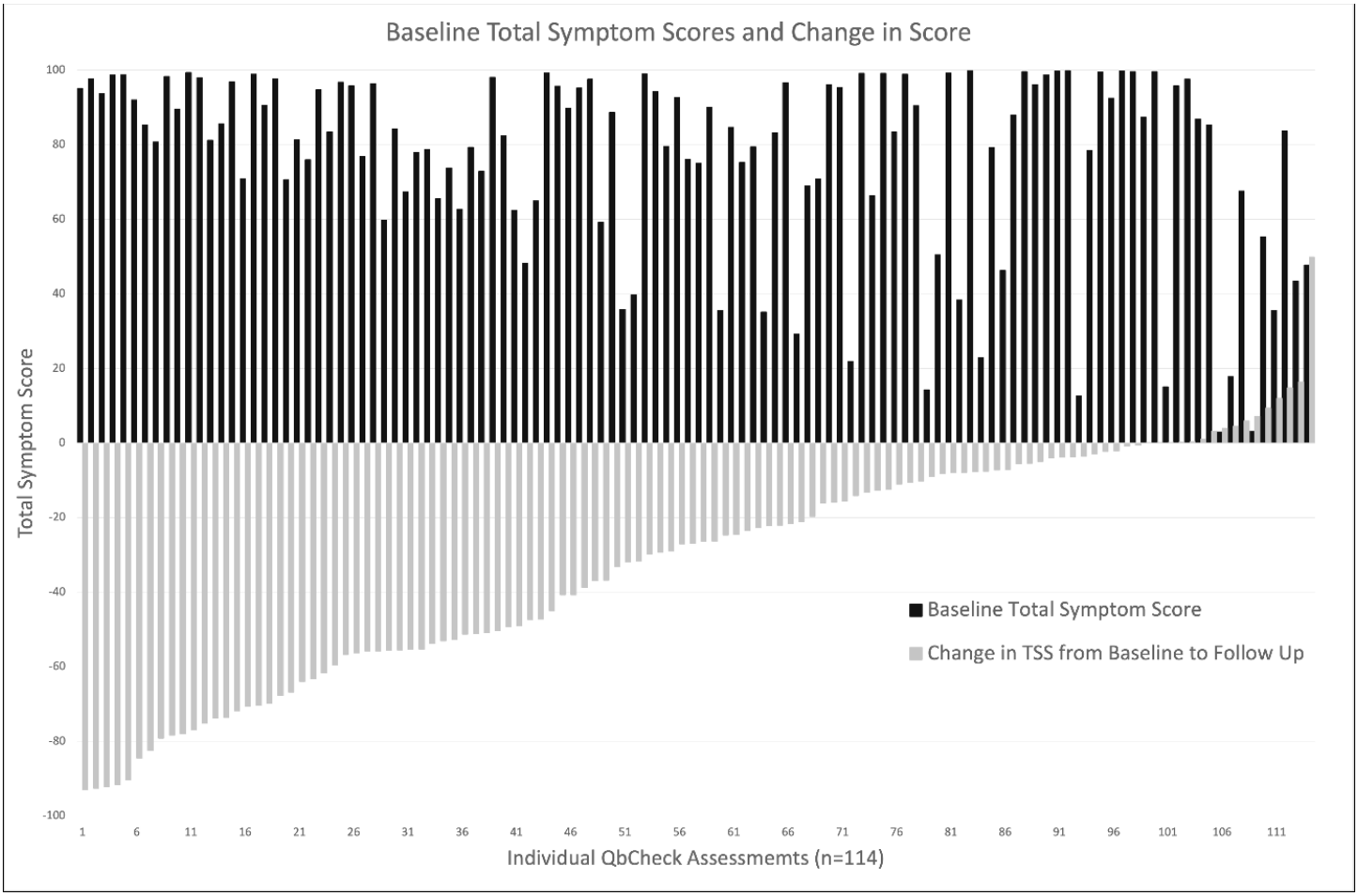

Figure 2: The individual data sets (n=114) of QbCheck Total Symptom Scores are shown at baseline along with their corresponding absolute change in Total Symptom Scores from baseline to follow-up assessments.

pharmaceutical treatment. The degree of response to medication and change in ADHD symptoms greatly varied among the 114 subjects. Even though most subjects showed a significant improvement in TSS, not all showed the same drastic decrease in ADHD symptom measurements. Utilizing this data during the decision-making and medication titration process, clinicians could optimize each patient on their medication that would balance their ADHD symptoms at the lowest effective dose [26]. This personalized approach would enhance treatment efficacy and foster a more collaborative relationship between healthcare providers, patients, and caregivers.

Moreover, objective assessments offer a standardized and reliable means of evaluating treatment response across diverse clinical settings and longitudinal time frames [25]. By employing objective metrics, clinicians can track changes in ADHD symptom severity more consistently, allowing for better- informed treatment decisions and improved communication among stakeholders.

The clinical significance of the observed improvement in QbCheck scores extends beyond mere symptom reduction. Enhanced ADHD symptom management may translate into tangible improvements in various domains of functioning, including academic performance, social interactions, and overall quality of life for individuals with ADHD. Martin-Key et al., 2022 suggests that discrepancies between measured objective and subjective treatment effects could reflect the delay between optimized treatment of medical symptoms and subsequent changes in the development of new habits or life skills used in day-to-day environments [25]. Therefore, objective measures, such as the QbTest or QbCheck, are likely more sensitive to physiological changes and could be effective in early detection of treatment effects.

Telehealth, digital technologies and platforms have become more prominent in the last several years to enhance access and support treatment strategies in mental health disorders [27-29]. In a recent meta- analysis review the impact of digital interventions on medication adherence in pediatrics with ADHD and/or related neuropsychiatric disorder gave inconclusive evidence regarding improvement of medication compliance in children and adolescents, though digital interventions were shown to help bridge the gaps between patients and healthcare professionals, allowing for more frequent monitoring, communication, and assessments [29]. Nevertheless, digital telehealth technology may be a powerful instrument in monitoring ADHD pharmacological treatment, which could lead to new opportunities for development

of individualized conduct medication interventions such as remote monitoring of symptoms [30].

One important limitation of this investigation was that only patients who had two QbCheck assessments at least 24 hours apart and selected the option indicating medication treatment during the follow-up assessment were included as part of this analysis, therefore constraining the number of subjects used for this investigation. Additionally, as this was a post-hoc analysis, there was limited access to more comprehensive comparative data that could be used. It would be important to conduct additional studies using more robust inclusion criteria, further evaluating the effects and benefits of treatment monitoring using objective testing, in both a clinical and remote setting, along with comparing changes in subjective measures with changes in objective measures post treatment. The compelling evidence of reduced ADHD symptoms post-ADHD medication treatment underscores the pivotal role of pharmacotherapy in managing ADHD. Objective assessments like the QbCheck serve as invaluable tools in guiding treatment decisions, monitoring progress, and optimizing treatment outcomes for individuals with ADHD. Additionally, the benefits of remote objective testing, such as QbCheck, can be seen and integrated in the monitoring of patient care and treatment via telehealth and beyond.

Conflict of Interest

The authors are employed at either Qbtech, Inc Houston, TX, USA or Qbtech AB, Stockholm, Sweden, the company that manufactures QbCheck. The writing and evaluation of the manuscript was developed within the medical department but was not influenced by Qbtech AB.

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