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Are reading abilities and verbal working memory related in boys with Duchenne Muscular Dystrophy?

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Abstract

Duchenne Muscular Dystrophy is a hereditary x-linked disease which causes progressive muscle weakness, and approximately 1 in every 3500 boys is affected. The current study compared information processing skills, verbal working memory and behavioral functioning of 78 Dutch boys with Duchenne Muscular Dystrophy (mean age 10.0 years) with the population mean. Reading performance was measured in 44 boys with Duchenne Muscular Dystrophy and the association between verbal working memory and reading performance was investigated by correlations and by investigating possible differences in reading abilities between boys with an average or normal verbal working memory and boys with a low verbal working memory. The results showed that boys with Duchenne Muscular Dystrophy have poor information processing skills, poor verbal working memory, and poor reading skills in comparison with the normal population. 61% Of the boys with Duchenne Muscular Dystrophy had reading problems, of which 36% had serious reading problems. Reading problems appear to be related to verbal working memory abilities rather than to parent-rated attention problems. An early and systematic screening of boys with Duchenne Muscular Dystrophy is suggested to detect possible verbal working memory problems which might indicate that they are at risk of reading problems at an older age.

Keywords: Duchenne Muscular Dystrophy, cognition, reading abilities, verbal working memory

Introduction

Duchenne Muscular Dystrophy (DMD) is a hereditary x-linked disease first described by the French physician Duchenne de Boulogne in 1868. DMD causes progressive muscle weakness, and approximately 1 in every 3500 boys is affected (Emery, 1993; Emery, & Muntoni, 2003; Karagan, 1979). It is the most common and fatal form of the muscular dystrophies with a childhood-onset (Culligan et al., 1998). The disease is caused by a mutation of the dystrophin gene. Boys with DMD are not able to produce detectable dystrophin due to this mutation. Normally, the dystrophin gene is found at the sarcolemma in skeletal muscle, and at postsynaptic densities in the central nervous system (CNS), especially in the cerebral cortex, hippocampus, and in Purkinje Cells (Anderson, Head, & Morley, 2012; Hoffman, 1987). Although the function of dystrophin in cognitive or other neurobehavioral characteristics are less well understood than its physiological function in muscles, researchers presume a relationship between the lack of dystrophin and cognitive impairments within boys with DMD (Anderson et al., 2012).

The cognitive profile of boys with DMD is described with a mean Wechsler Full Scale IQ of approximately 1 standard deviation below the population mean (Cotton, Voudouris, & Greenwood, 2001). About one-third of the boys with DMD exhibit mild mental retardation (Cotton et al., 2001). Furthermore, boys with DMD have deficits in information processing (Hendriksen, & Vles, 2006; Perumal, Rajeswaran, & Nalini, 2015) and in verbal working memory (Billard, Gillet, Barthez, Hommet, & Bertrand, 1998; Billard et al., 1992; Dorman, Hurley, & D’Avignon, 1988; Hinton, Nereo, De Vivo, Goldstein, & Stern, 2000; Perumal, Rajeswaran, & Nalini, 2015; Smith, Sibert, & Harper, 1990). Verbal working memory is defined as a system that provides temporal storage of verbal information that can be used to support ongoing cognitive activities (Baddely, & Hitch, 1974). In previous research, different terms and different instruments were used to measure verbal working memory, but most studies used instruments that require listening to and accurately repeating verbal information, which is presented only once (Hinton, De Vivo, Fee, Goldstein, & Stern, 2004). The deficits in verbal working memory of boys with DMD are irrespective of general intellectual functioning (Hinton et al., 2000). However, the hypotheses of a specific neuropsychological profile characterized by a deficit in verbal working memory has not been universally supported. For example, Donders and Taneja (2009), found no deficits in immediate memory for verbal material in boys with DMD. Thus, literature is not conclusive on a verbal working memory deficit in boys with DMD and there is still debate about the specific neuropsychological profile of these boys.

Impairment in verbal abilities among boys with DMD can have an enduring impact and negative effect on learning, emotional adjustment and peer interactions. Learning disabilities are more common in boys with DMD, particularly those involving reading skills. Language and reading skills, from a neuropsychological point of view, strongly related and can be considered as a continuum (Bishop & Snowling, 2004). Dorman et al. (1988) found that half of the boys with DMD show deficient reading or spelling skills and Billard et al. (1998) also reported that boys with DMD had reading difficulties (mean reading quotient of 85%), however, reading performance varied considerably. These findings are in line with the observation of Leibowitz and Dubowitz (1981), who already observed in 1981 that ‘a considerable number of Duchenne muscular dystrophy children were particularly handicapped in reading’ (page 586). Moreover, approximately 40% of boys with DMD demonstrate moderate reading problems and 20% have serious reading difficulties (Hendriksen, & Vles, 2006).

Investigators searched for an explanation for the reading problems of boys with DMD. Billard et al. (1998) excluded a psycho-affective explanation for the reading difficulties and Hendriksen and Vles (2006) and Hinton et al. (2004) excluded an association between reading scores and either motor impairment or parent-rated behavioral problems such as attention problems. The finding that there is no association between reading scores and parent-rated attention problems in boys with DMD is not in line with findings about the association between reading skills and attention problems in boys without DMD. August and Garfinkel (1989), Dykman and Ackennan (1991), Faraone et al. (1993), Lambert and Sandoval (1980) and Semrud-Clikeman et al.(1992) found, for example, that a considerable proportion of boys with ADHD meet criteria for a diagnose of reading disability. Moreover, Rabiner and Coie (2000) found that attention problems predicted reading performance even after controlling for prior reading performance, other behavioral difficulties and IQ. Alloway and Alloway (2010) found another predictor of academic attainment in typically developing children. They reported that working memory is a powerful predictor of reading skills, even more powerful than IQ (Alloway & Alloway, 2010). With reading, children need to learn the pattern of written words and how to switch between sounds of the language and written letters to recognize and spell words that are not yet in their visual dictionary. Children with a low verbal working memory have difficulties learning how to switch between the sound of the familiar words and their spelling, which limits their ability to read and spell separate words. Besides difficulties with word recognition, children with a low working memory also have difficulties storing and understanding the words (Gathercole & Alloway, 2013). Therefore, the impairment in reading abilities in boys with DMD might be caused by the defect in verbal working memory (Hinton et al., 2000; Wicksell, Kihlgren, Melin, & Eeg-Olofsson, 2004). Hinton et al. (2004) found that scores of academic achievement (reading, writing and math) in boys with DMD could be predicted by performance on a verbal working memory task (Digit Span).

Overall there are only four studies which report reading disabilities in boys with DMD (Billard et al., 1998; Dorman et al., 1988; Hendriksen, & Vles, 2006; Leibowitz, & Dubowitz, 1981). Sample sizes were very small in three of these studies (sample sizes of less than 26 boys) and the study of Leibowitz and Dubowitz (1981) had a larger sample size of 42 boys. Furthermore, the relation between reading skills and the possible role of verbal working memory in boys with DMD was not investigated. The identification of specific cognitive and academic deficits and the underlying causes are crucial to the understanding of the general psychological profile of boys with DMD, with implications both for diagnostic testing and therapeutic intervention (Birnkrant, Bennett, Noritz, & Birnkrant, 2011).

Reading is important for later education, and particularly in boys with DMD who have progressive muscle weakness and rely more and more on communication by reading and spelling. Early detection of and interventions for reading problems might improve the development of reading skills in those boys who are at risk for future reading disabilities (Hendriksen, & Vles, 2006). Therefore, the aim of the current study is to validate earlier findings of reading abilities in a larger cohort of boys with DMD and to further systematically assess the possible association between reading performance and a limited verbal working memory. We expected that reading disabilities are more common among boys with DMD than in healthy boys and that there is a significant positive correlation between reading abilities and verbal working memory in boys with DMD. Verbal working memory of boys with DMD is expected to be significantly lower than the population mean. Furthermore, information processing skills, parent-rated attention problems and reading abilities are expected to differ between boys with an average or higher verbal working memory and boys with a less than average verbal working memory. To be more certain about the absence of an association between reading performance and attention problems in boys with DMD, contrary to boys without DMD, the final aim of the present study is to validate earlier findings about this association in a larger cohort of boys with DMD. If there is indeed no association between reading performance and attention problems in boys with DMD, systematic screening programs for boys who are at risk of reading problems should not be aimed at attention problems.

Methods

Participants

Data from 78 Dutch boys with DMD (mean age 10.0 SD 3.2) were included in the study. These patients were recruited from existing datasets and our outpatient clinic (Kempenhaeghe, Centre of neurological learning disabilities, Heeze, the Netherlands). The boys with DMD and their parents live in different parts of the Netherlands. 45 (58%) of the boys visit a normal school and 33 (42%) of them attend a special school for children with a physical handicap or with special attention and support. All participants completed a neuropsychological test battery. There were no exclusion criteria.

Task and stimuli

Neuropsychological testing consisted of a battery for assessing specific cognitive functions, reading skills and parent-rated behavior problems. In the current study, reading problems were defined as poor reading skills in the context of normal intellectual capacities (see below). Intellectual capacities were measured by tests which would be minimally influenced by motor impairment including information-processing skills tested with the Kaufman Assessment Battery for Children (KABC-II) (Kaufman, & Kaufman, 2004). With this test, two different types of information-processing can be assessed, namely sequential processing and simultaneous processing. Sequential processing involves arranging verbal input in sequential or serial order to solve a problem. Simultaneous processing refers to the ability to integrate and synthesize input simultaneously (holistically), usually visuo-spatially, to produce the appropriate solution (Kaufman, & Kaufman, 2004). The score on the subtest ‘number recall’ from the sequential processing scale was used as a measurement for verbal working memory and the score of the subtest ‘block counting’ from the simultaneous processing scale was used as a measurement for spatial awareness. Furthermore, word comprehension and receptive vocabulary were measured by the Peabody Picture Vocabulary Test (PPVT-III) (Dunn, & Dunn, 2005) in order to have a verbal measure of intellectual capacities.

Reading abilities were assessed with subtests of Dutch word reading tasks (Continuous Naming and Word Reading (CB&WL) and the Three Minutes Test (DMT): Bos, & Lutje Spelberg, 2007; Jongen, & Krom, 2009) and a standardized non-word reading task (Klepel: Bos, Lutje Spelberg, Scheepsma, & Vries, 1994). Subtests of the CB&WL, tasks in which children have to read two cards of progressively more difficult words, results in a standard score with a mean of 10 and an SD of 3 (Bos, & Lutje Spelberg, 2007). During the DMT, the boys with DMD have to read three cards of progressively more difficult words (Jongen, & Krom, 2009). Reading age equivalent is divided by chronological age and results in the Learning Efficiency Quotient (LEQ). Children were regarded learning disabled if the LEQ is 85% or lower and a LEQ of 70% or lower was considered as having serious reading problems (Hendriksen & Vles, 2006). The Klepel, a task in which children have to read as many non-words as they can, results in a standard score with a mean of 10 and an SD of 3 (Bos et al., 1994). The standard score of all the reading tasks was based on both reading speed and reading accuracy.

Attention problems were measured by the Child Behavioral Checklist (CBCL), which was completed by parents (Verhulst, Koot, Akkerhuis, & Veerman, 1996). This parent-report questionnaire, by proxy, measures eight subscales including the scale ‘attention problems’. A T-score of 70 or higher indicates that the attention problems are in the clinical range.

Procedure

Data were collected in an outpatient clinic in the Netherlands, Kempenhaeghe, from clinical protocols in which boys with DMD were studied. The center of neurological learning disabilities of Kempenhaeghe is an outpatient expertise center for children with neurological disorders and comorbid learning disabilities. Data were also collected from existing empirical protocols (reading study Leiden (Hendriksen & Vles, 2006) and the follow-up study (Doorenweerd et al., 2014)). The sample size of the reading study Leiden exists of 30 boys with DMD and the follow-up study exists of 32 boys with DMD. All the boys with DMD were studied by the supervisor (J. Hendriksen) of the center of neurological learning disabilities of Kempenhaeghe. For further details of the collected data see Table 1.

Analyses

Descriptive statistics about the information processing skills of the included boys with DMD, their verbal working memory scores, their parent-rated attention problems and reading abilities were calculated in Statistical Package for the Social Sciences (SPSS) version 21.0 (Pallant, 2010). Shapiro Wilk tests for normality were computed. Furthermore, one sample t-tests were executed to compare information processing skills, verbal working memory and parent-rated attention problems of the boys with DMD with the population mean.

The boys with DMD were classified according to their severity of reading problems. Reading skills were classified as severe reading problems when the score for word-reading was 2 SD below the mean and one of the scores for information processing from the KABC-II (sequential or simultaneous) was in the normal range (score of >85). In the absence of information processing scores, one of the scores on the PPVT and the subtest ‘Block Counting’ from the KABC-II had to be in the normal range (score of >85 for the PPVT and a score of >7 for Block Counting) for the classification of severe reading problems. Moderate reading problems were present when information processing scores or scores on the PPVT and ‘Block counting’ were in the normal range again and when the score for word-reading was 1 SD below average. Normal reading was present when the score for word-reading was average or higher. Reading skills were classified as ‘nondiscrepant reading’ when information processing scores or scores on the PPVT and ‘Block counting’ were both below the normal range and the score for word-reading was at least 1 SD below average.

Nonparametric binomial tests were executed to compare incidence rates of reading problems of boys with DMD with the incidence rate of the normal population of 10% (Bishop, & Snowling, 2004; Habib, 2000; Lundberg, 2002) and incidence rates from previous studies. Furthermore, a one-sample t-test was computed to compare the reading quotient of boys with DMD from the present study with the reading quotient from a previous study.

Pearson product-moment correlation coefficients were calculated between reading abilities and verbal working memory. A one-sided test for significance was used because a positive correlation is expected between reading abilities and verbal working memory in boys with DMD. Pearson product-moment correlation coefficients were also calculated between reading abilities and parent-rated attention problems. Since no significant correlation is expected, an two-sided test for significance was used. Independent-samples t-tests (two-tailed) were executed to find possible differences on information processing skills, parent-rated attention problems and reading abilities between boys with an average or higher verbal working memory and boys with a less than average verbal working memory.

The level of significance was set at $P < .05$ for all tests. Bonferroni adjustments to the alpha were performed in order to reduce the risk of type 1 errors. Finally, power analyses were conducted on the Pearson product-moment correlation coefficients and the independent samples-samples t-tests.

Results

Table 2 presents descriptive statistics and a normality test for the specific cognitive skills, parent-rated attention problems and reading scores of the boys with DMD. The assumption of normality is violated for attention problems (W(68) = .86, p < .001). Although, this violation of the normality assumption should not cause major problems because the sample size of 68 is large enough (> 30 or 40) (Pallant, 2007). For large sample sizes, significant results would be derived even in the case of a small deviation from normality (Field, 2009; Oztuna, Elhan, & Tuccar, 2006), although this small deviation will not affect the results of a parametric test (Oztuna, Elhan, & Tuccar, 2006).

The mean sequential processing score and simultaneous processing score of the boys with DMD on the KABC-II were significant lower than the population mean of 100 (SD 15) (M = 84.77, SD = 15.48; *t* (47) = - 6,817, *p* < .001, d = -1.00 and M = 93.30, SD = 16.30; *t* (45) = - 2.786, *p* = .008, d = -.43 respectively). The level of significance was adjusted to .013 because four t-tests were performed. Another one-sample t-test was conducted to compare the mean score of verbal working memory of boys with DMD with the population mean of 10 (SD 3). The test revealed that boys with DMD have a significant lower verbal working memory than the population mean (M = 7.48, SD = 2.73; *t* (76) = -8.093, *p* < .001, d = -.88). Furthermore, a one-sample t-test was computed to compare the mean score of the parent-rated attention problems for boys with DMD with the population mean of 50 (SD 10). The mean score of the boys with DMD was significantly higher than the population mean (M = 55.93, SD = 6.33; *t* (67) = 7.721, *p* < .001, d = .71) but the score was not in the clinical range.

The average score for the reading task (CB&WL) was 6.47 (SD 3.01). The mean LEQ (DMT) was 57% (SD 29.08) and the average score for the non-word reading task (Klepel) was 7.65 (SD 3.30). In total, 16 of the 44 boys with DMD (36%) fulfilled the criteria of severe reading problems. A nonparametric binomial test revealed that this incidence rate of

36% was significantly higher than the incidence rate of the normal population (x = 16, n = 44, $p < .001$, d = .77, alternative = “greater”). The level of significance was adjusted to .01 because five analyses (four nonparametric binomial tests and one one-sample t-test) were performed. Of all the 44 boys, 11 (25%) fulfilled the criteria of moderate reading problems and 12 (27%) had normal reading scores. Finally, 5 of the 44 boys (11%) had reading problems but their reading skills were in accordance with their cognitive capacities (nondiscrepant reading). The percentage of boys with reading problems (severe and moderate reading problems) was approximately 60% in both measurements (with CB&WL, sequential and simultaneous processing scores and with DMT, PPVT and ‘Block counting’ scores). A nonparametric binomial test revealed that the incidence rate of reading problems (severe reading problems and moderate reading problems) of boys with DMD of 61% in the present study was not significantly different from the finding of Dorman et al. (1988), who reported that 50% of the boys with DMD have reading problems (x = 27, n = 44, $p = .174$, d = .24, alternative = “greater”). Furthermore, the found mean reading quotient of 57% was lower than the mean reading quotient of 85% reported by Billard et al. (1998). A one-sample t-test was conducted and revealed that the quotient of 57% from the present study was significant lower than the mean reading quotient among boys with DMD reported by Billard et al. (1998) (M = 56.74, SD = 29.08; t (18) = -4.237, $p < .001$, d = -1.99). Comparing with the findings of Hendriksen and Vles (2006) concerning reading problems (40%) and serious reading problems (20%), the present findings of 61% and 36% were significant higher which is revealed by nonparametric binomial tests (x = 27, n = 44, $p = .003$, d = .47, alternative = “greater” and x = 16, n = 44, $p = .009$, d = .40 , alternative = “greater” respectively).

The relationship between verbal working memory and reading skills was investigated using Pearson product-moment correlation coefficients. Preliminary analyses were performed to ensure no violation of the assumptions of linearity and homoscedasticity. Table

3 shows a positive association between verbal working memory and reading skills. The level of significance was adjusted to .009 because six Pearson product-moment correlation coefficients were calculated. A significant medium correlation between verbal working memory and word reading skills (CB&WL) was found (r = .447, n = 30, p = .007). With the adjusted alpha level, no significant correlations were found between word reading skills (DMT) and non-word reading skills (Klepel). The executed correlations between verbal working memory and word reading skills (CB&WL) and verbal working memory and non-word reading skills (Klepel) had an acceptable power value of .80 or higher (.90 and .82 respectively) (Pallant, 2010). The correlation between verbal working memory and word reading skills (DMT) had a power value less than .80.

The relationship between parent-rated attention problems and reading skills was also investigated using Pearson product-moment correlation coefficients. No significant correlations were found between parent-rated attention problems and reading skills measured with the CB&WL, DMT and Klepel. The executed correlations between parent-rated attention problems and reading skills all had a power value less than .80 (.27, .06 and .11 respectively).

Independent-samples t-tests were conducted to explore possible differences in sequential information processing, simultaneous information processing, parent-rated attention problems and reading abilities in boys with DMD with a different verbal working memory (Group 1: average or higher verbal working memory, called normal/high verbal working memory (N=40); Group 2: below average verbal working memory, called low verbal working memory (N=37)). The level of significance was adjusted to .006 because nine independent t-tests were performed. As can be seen in Table 4, sequential- and simultaneous information processing skills and word reading abilities (DMT) were significantly lower in boys with low verbal working memory than in boys with normal/high verbal working memory. The power value of the executed independent-samples t-test on word reading abilities (DMT) was acceptable (.91). The power value of the independent-samples t-tests on reading abilities (CB&WL and Klepel) had power values of .26 and .78 respectively, which is less than the required value of .80. Parent-rated attention problems did not differ. The independent-sample t-test on parent-rated attention problems had a power value of .13, which is less than the required .80.

Discussion

The aim of the current study was to validate earlier findings on reading abilities in a larger DMD group and to further systematically assess the association between reading performance and verbal working memory. The current study was also aimed at validating the finding of no association between parent-rated attention problems and reading difficulties in a larger cohort of boys with DMD to be more certain at which aspects systematic screening programs should be aimed for boys with DMD who are at risk for reading problems. In contrast with the studies from Billard et al. (1998) and Dorman et al. (1988) but in line with Hendriksen and Vles (2006), the current study used the 'discrepancy criterion' to classify reading problems in different groups of severity. This means that the reading performances of the boys with DMD were compared with their information processing skills in order to classify the different groups.

Boys with DMD were found to have low scores on reading tasks. Of the boys with DMD, 36% had severe reading problems and 25% had moderate reading problems. The reading abilities of these boys were lower than expected, based on their average information processing skills. Furthermore, 27% had normal reading scores and 11% of the boys fulfilled the criteria for 'nondiscrepant reading', which means that the reading problems were in accordance with the level of information processing. The incidence rate of severe reading problems in boys with DMD of 36% was higher than the incidence rate of 10% of the normal population (Bishop, & Snowling, 2004; Habib, 2000; Lundberg, 2002). The present study found a comparable result to the finding of Dorman et al. (1988) with an incidence rate of reading problems (severe reading problems and moderate reading problems) of 61%. Comparing with the findings of Billard et al. (1998) and Hendriksen and Vles (2006), the boys with DMD from the current study demonstrated a higher prevalence of reading problems and more severe reading problems. Thus the reading disabilities of boys with DMD appear to be worse than previously thought. Because Billard et al. (1998) and Hendriksen and Vles (2006) all used validated and standardized instruments to measure reading abilities, the different findings in this study can not be explained by the different instruments used. A possible alternative explanation for the discrepant findings is a different recruitment of the participants.

Furthermore, the current study showed that boys with DMD have a lower verbal working memory and lower information processing skills than the population mean, which is in line with the literature (e.g. Hendriksen, & Vles, 2006; Hinton et al., 2000; Perumal, Rajeswaran, & Nalini, 2015). Parent-rated attention problems were higher for boys with DMD than for the normal population. The differences found between boys with a normal/high verbal working memory and boys with a low verbal working memory indicates that the different verbal working memory groups appear to differ not only in verbal working memory, but also in reading abilities and information processing skills. In addition, a medium positive correlation was found between verbal working memory and reading abilities in boys with DMD. These findings are in line with the reported relationship between academic achievement and performance on a verbal working memory task as reported by Hinton et al. (2004). Indeed, there is a large amount of literature reporting an association between verbal working memory and reading scores in heterogeneous populations of children and students (e.g. Adams & Gathercole, 2000; Alloway, Gathercole, Kirkwood, & Elliott, 2009; Hitch, Towse, & Hutton, 2001). The different verbal working memory groups did not differ in parent-rated attention problems, however, this result is questionable because of the low power value.

Between parent-rated attention problems and reading abilities no correlations were found, however, this result is also questionable because of the low power values. Nevertheless, the present finding of no significant correlations between parent-rated attention problems and reading abilities is comparable to the findings of Hendriksen and Vles (2006) and Hinton et al. (2004) and different from the findings in the normal population. Although, the CBCL is one of the most frequently used measures for the assessment of domains of competence and behavior problems, some researchers have suggested that its use may not always be appropriate for chronically ill children (Perrin, Stein, & Drotar, 1991; Walker et al., 1990). A more extensive study with alternative methods to measure attention problems and more participants, and thus a higher power value than the values in the present study, is required to further validate the absence of a correlation between reading abilities and attention problems in boys with DMD.

A possible limitation of the present study is that different instruments were used for the determination of the discrepancy criterion to classify reading problems. Future studies should collect data from boys with DMD with the same instruments, because in this way data are more standardized. Another methodological drawback of the present study was that power values concerning analyses on parent-rated attention problems were low. The present study might have been too small to detect any differences in parent-rated attention problems because of the low power values. Another limitation of the current study might be that a control group was not used. However, the results from this study were analyzed in comparison with existing data from the population and/or with earlier findings from Billard et al. (1998), Dorman et al. (1988) and Hendriksen and Vles (2006). Furthermore, the sample size of the present study is greater than most of the previous reported studies on reading abilities and most of the power values concerning reading abilities were high. Therefore, the data from the present study do have clinical importance.

In conclusion, boys with DMD are at a higher risk of developing both verbal working memory problems as reading problems than boys from a normal population, independent of parent-rated attention problems. Moreover, the higher risk of reading problems appears related to verbal working memory. Further research is needed to investigate the causality of this relationship. A systematic screening of boys with DMD is suggested at age 4 to detect possible verbal working memory problems which might indicate that they are at risk of reading problems at an older age. It is important to perform the systematic screening at the earliest possible age because it is likely that the effect of low verbal working memory is cumulative across development. Due to the low verbal working memory, the process of acquiring reading skills and knowledge over the school years is disrupted, which might result in greater decrements in reading abilities as a child gets older in comparison with peers (Alloway, 2006). Early screening is important as there is now substantial evidence that working memory capacity can be increased by intensive training by the Cogmed method (e.g. Chacko et al., 2013; Dahlin, 2011; Klingberg, 2010). Although the effectiveness of working memory training requires much more research, boys with DMD with a low verbal working memory might benefit from this intensive training. Besides, boys with DMD with a low verbal working memory might benefit from educational interventions such as repeating verbal instructions and breaking extensive verbal information into smaller sections (Hinton et al., 2004). Finally, phonological awareness, next to verbal working memory, might play a crucial role in the development of reading skills (Bishop, & Snowling, 2004; Habib, 2000; Lundberg, 2002; Vellutino, Fletcher, Snowling, & Scanlon, 2004) and can be trained in preschool programs. Healthy children who are at risk for reading problems have been shown to benefit from such programs (Lundberg, 2002; Vellutino et al, 2004). Research on intervention strategies and reading problems and verbal working memory training in boys with DMD have not yet been described but are necessary in the near future.

Table 1: Number of patients collected from existing empirical protocols (Reading study Leiden and Follow-up study) and Kempenhaeghe (outpatient clinic)

	KABC-II: Seq	KABC-II: Sim	KABC-II: NR	KABC-II: BC	PPVT: WBQ	CBCL: Attention problems	CB&WL: WR	DMT: LEQ	Klepel	**Total**
Reading study Leiden	0	0	30	28	30	28	25	0	0	**30**
Follow-up study	32	32	32	0	0	31	0	19	20	**32**
Outpatient clinic	16	14	14	2	3	8	5	0	0	**16**
Total	**48**	**46**	**76**	**30**	**33**	**67**	**30**	**19**	**20**	**78**

Seq = Sequential, Sim = Simultaneous, NR = Number Recall, BC = Block Counting, WBQ = Word Comprehension Quotient, WR = Word Reading, and LEQ = Learning Efficiency Quotient

Table 2: Information processing scores, verbal working memory, parent-rated attention problems, and reading scores for the boys with DMD

	KABC-II: Seq	**KABC-II: Sim**	**KABC-II: NR**	**KABC-II: BC**	**PPVT: WBQ**	**CBCL: Attention problems**	**CB&WL: WR**	**DMT: LEQ**	**Klepel**
N	48	46	76	30	33	67	30	19	20
Mean	84.77	93.30	7.47	10.23	95.82	55.97	6.47	56.74	7.65
SD	15.48	16.30	2.75	3.50	17.53	6.37	3.01	29.08	3.30
Min	48	64	1	2	55	50	1	18	2
Max	113	139	14	19	129	78	12	115	13
Shapiro-Wilk	.98	.96	.98	.96	.97	.86**	.97	.92	.92

Seq = Sequential, Sim = Simultaneous, NR = Number Recall, BC = Block Counting, WBQ = Word Comprehension Quotient, WR = Word Reading, and LEQ = Learning Efficiency Quotient

*** Significant at p < .01 (2-tailed).*

** Significant at p < .05 (2-tailed).*

Table 3. Pearson product-moment correlation coefficients

	CB&WL: Word reading	**DMT: LEQ**	**Klepel**
KABC-II: Number recall	.45* (30)(.90)	.44 (19)(.72)	.47 (20)(.82)
CBCL: Attention problems	-.28 (27)(.27)	.07 (18)(.06)	-.17 (19)(.11)

Data presented as correlation coefficient (sample size)(power)

LEQ = Learning Efficiency Quotient

*** Significant correlation at* $p < .01$

** Significant correlation at* $p < .05$

Table 4: Descriptive statistics and independent-sample t-test values of the two groups of verbal working memory

	KABC-II: Seq	**KABC-II: Sim**	**KABC-II: NR**	**KABC-II: BC**	**PPVT: WBQ**	**CBCL: Attention problems**	**CB&WL: WR**	**DMT: LEQ**	**Klepel**
Normal/high VWM	95.79	101.00	9.63	11.00	101.50	55.24	7.19	75.78	9.50
	(8.96) (24)	(17.34) (23)	(1.58) (40)	(3.06) (17)	(18.00) (18)	(5.49) (37)	(2.90) (16)	(28.40) (9)	(2.64) (10)
Low VWM	71.78	84.43	5.16	9.43	90.00	56.73	5.64	39.60	5.80
	(10.53) (22)	(10.56) (21)	(1.55) (37)	(3.82) (14)	(14,80) (16)	(7.33) (30)	(3.03) (14)	(16.88) (10)	(2.90) (10)
***T*-value**	-8.35**	-3.78**	-12.48**	-1.27	-2.02	.95	-1.43	-3.42*	-2.99
Power	1.0	.99	1.0	.27	.51	.13	.26	.91	.78

Data presented as mean (SD)(sample size)

VWM = Verbal Working Memory, Seq = Sequential, Sim = Simultaneous, NR = Number Recall, BC = Block Counting, WBQ = Word Comprehension Quotient, WR= Word Reading, and LEQ = Learning Efficiency Quotient

*** Significant at $p < .01$ (2-tailed) with an Independent-samples t-test*

** Significant at $p < .05$ (2-tailed) with an Independent-samples t-test*

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