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ORIGINAL ARTICLE

Developmental dysgraphia is often associated with minor neurological dysfunction in children with developmental coordination disorder (DCD)

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Summary
Objectives. — Children with developmental coordination disorder (DCD) are particularly affected by handwriting disorders, which remain poorly understood and are not clearly defined. The aim of our study is to provide a better understanding of handwriting disorders, and specifically of dysgraphia in children with DCD.
Methods. — Sixty-five children with DCD (5—15 years), enrolled according to DSM-5, were assessed with handwriting testing and standardized assessments of neuropsychological, neurovisual, MRI and neuropsychomotor functions, with special attention paid to muscular tone examination.
Results. — While handwriting disorders were strongly represented in our sample of children with DCD (89%), dysgraphia appeared uncommon (17%) and was closely related to several specific dysfunctions of laterality establishment; mild pyramidal tract dysfunction with distal phasic stretch reflex (PSR) in lower limbs; digital praxis slowness (both $P < 0.05$).
Discussion. — In our sample, dysgraphia was closely related to minor neurological dysfunction (MND) suggesting a disturbance of motor control at the level of the corticospinal motor pathway.

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This highlights the uncommon character of dysgraphia in children with DCD for which diagnosis should be made through a particular attention to evaluation of MND with muscular tone examination. This consideration, both in the research setting and in clinical practice, appears necessary to avoid inaccurate clinical diagnosis and to optimize appropriate therapeutic management.

Introduction

Handwriting disorders are a public health issue, both in terms of frequency and in their consequences. Indeed, learning to write is a complex and multifactorial process requiring cognitive [17,46] perceptual-motor [16], and mental and emotional skills. It is mainly a motor process involving an efficient level of motor organization leading to fine coordination of movements [1,19]. Because of this complexity, some school-age children have handwriting disorders leading to psychological suffering at school and learning disabilities [14,20]. The estimated prevalence of handwriting disorders varies from 6 to 37% in typical school-aged children depending on studies, elementary grades, and case definition [29,36]. Children with developmental coordination disorder (DCD) are particularly affected, since up to 87—88% of this group is concerned [35,56]. However, in international classifications (DSM-5 [6]), handwriting disorders do not appear as fully-fledged disorders but are associated with other motor or specific learning neurodevelopmental disorders. There is currently no consensus on the definition and characteristics of handwriting disorders, and their etiology is poorly understood. A scientific literature review quickly highlights a wide range of terms used to qualify handwriting disorders: poor handwriting [24], handwriting dysfunction [23], dysgraphia [11], or handwriting learning disorder (including poor handwriting and dysgraphia) [10]. The definition of dysgraphia remains unclear: it has tended to refer, since the 1960s, to inadequate quality of writing without any neurological or intellectual impairments [1]. Some authors associate dysgraphia with spelling and memory difficulties while others associate it with motor impairments [10]. For some, dysgraphia is a special form of DCD, considered to be the consequence of poor planning of the motor action necessary to write [49]. Moreover, some studies make this diagnosis as soon as there is illegible writing, while others differentiate dysgraphia and poor handwriting depending on the degree of handwriting impairment [23,24]. In the current study, we differentiate between poor handwriting (PH) and dysgraphia (DysG), considering dysgraphia to be a marked degree of handwriting impairment in terms of legibility. The study of handwriting disorders in DCD is more complex because, despite an attempt of consensus on terminology, diagnosis, and intervention reached by a group of international scholars in DCD in 2012 [12], DCD remains poorly understood and studies do not use the same tools and diagnostic criteria to designate their groups of children with DCD. The DSM-5 [6] (or DSM-IV-TR [5]) diagnostic criteria are commonly used to classify children with DCD, in association with a global motor test expressing the child's performance with a total impairment score (mainly the Movement Assessment Battery for Children (MABC) [26]. However, there is no real consensus about semiology of DCD [54] nor about a suitable diagnostic cut-off of impairment, which alternates between 5th percentile [48] and 15th percentile [13] on the MABC test across studies. A recent study [56] highlighted and validated in-depth assessments of three subgroups of DCD with specific clinical criteria. The ideomotor subgroup (IM) incorporated mainly impairments in praxis, digital perception (gnosis) and gnosopraxis (imitation of hands and fingers gestures); the visuo-spatial and/or visual-constructional subgroup (VSC) displayed mainly visuo-spatial impairments (including dysgraphia); and the mixed subgroup (MX) involved IM, VSC and other specific disorders [32,56]. The study showed the necessity of using a complete qualitative and quantitative standardized neurodevelopmental assessment with children with DCD including minor neurological dysfunction (MND), in addition to neuropsychological examination. Regarding handwriting disorders (dysgraphia or poor handwriting), studies have primarily based their investigations on the writing product assessing legibility and speed, and/or on the handwriting process studying spatial-temporal organization, but without assessing comorbidities of handwriting disorders to obtain a better etiological understanding [13,28,39,47,48]. Thus, conclusions are restricted to poor handwriting, time management issues (handwriting velocity, frequency of time pauses) and/or programming and anticipation impairments manifested by a unitary treatment of letters [18,49] or by difficulty in switching from feedback to feedforward control of handwriting [27,40]. A recent study [33] attempted to clarify the nature of handwriting disorders in children with DCD highlighting six specific handwriting criteria exposing handwriting motor organization (detailed in Table 1) in children with DCD and with handwriting disorder. To our knowledge, only a few studies have examined neural correlates of handwriting [11,38,44] but without specific correlation between neuroimaging and handwriting disorders. Other studies with neurological approaches have shown the presence of minor neurological dysfunctions (MND) in children with dysgraphia but not specifically with DCD [57,58]. The relationship between MND and handwriting disorder (in DCD or not) remains poorly known.

It thus appears necessary to better specify handwriting disorders that are poorly understood and subject, in clinical practice, to imprecise clinical diagnoses with consequences for therapeutic options. In fact, handwriting disorders are often too succinctly assessed with a single test based on writing product only, without a comprehensive assessment of other functions involved in handwriting: mainly the Concise evaluation scale for children's handwriting (BHK [25]), the Minnesota Handwriting Assessment (MHA [41]), the Evaluation Tool of Children's Handwriting (ETCH [7]), and/or the Detailed Assessment of Speed of Handwriting (DASH [8]). The aim of this study is to better identify the nature of handwriting disorders (poor handwriting and dysgraphia) in

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