Clinical Neurophysiology 125 (2014) 786–797

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Task specific grip force control in writer's cramp

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See Editorial, pages 655–656

ARTICLE INFO

Article history:
Available online 13 November 2013

Keywords:
Writer's cramp
Focal dystonia
Handwriting
Force analysis
Grip force

HIGHLIGHTS

- Writer's cramp increased grip force to hold the pen during handwriting but not to lift and move objects.
- Patients with writer's cramp did not generalize grip force levels across manipulation tasks.
- Grip force regulation during handwriting in writer's cramp is task-specific and individualised.

ABSTRACT

Objective: Writer's cramp is defined as a task specific focal dystonia generating hypertonic muscle co-contractions during handwriting resulting in impaired writing performance and exaggerated finger force. However, little is known about the generalisation of grip force across tasks others than writing. The aim of the study was to directly compare regulation of grip forces during handwriting with force regulation in other fine-motor tasks in patients and control subjects.
Methods: Handwriting, lifting and cyclic movements of a grasped object were investigated in 21 patients and 14 controls. The applied forces were registered in all three tasks and compared between groups and tasks. In addition, task-specific measures of fine-motor skill were assessed.
Results: As expected, patients generated exaggerated forces during handwriting compared to control subjects. However there were no statistically significant group differences during lifting and cyclic movements. The control group revealed a generalisation of grip forces across manual tasks whereas in patients there was no such correlation.
Conclusion: We conclude that increased finger forces during handwriting are a task-specific phenomenon that does not necessarily generalise to other fine-motor tasks.
Significance: Force control of patients with writer's cramp in handwriting and other fine-motor tasks is characterised by individualised control strategies.

1. Introduction

Writer's cramp (WC) is considered as a task-specific form of focal hand dystonia with uncontrollable muscle co-contraction of hand and arm muscles during writing are the cardinal symptoms of Writer's cramp. Writer's Cramp typically affects persons who have spent periods engaged in stereotyped and repetitive writing (Hallett, 2006). The script of patients with WC may still be legible, but script production is awkward, strenuous and slowed with the production of non-ergonomic, squashed and tremulous letters. Patients frequently report pain and loss of pen control during handwriting.

Two forms of writer's cramp have been distinguished according to the co-occurrence of deficits in other fine motor tasks (Gowers, 1888; Sheehy and Marsden, 1982). In simple writer's cramp (sWC) symptoms only occur while holding a pen and performing writing or drawing movements, while other manual tasks are carried out

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1388-2457/$36.00
http://dx.doi.org/10.1016/j.clinph.2013.09.043

normally. By contrast, patients with dystonic or complex writer's cramp (cWC) also report decrements of skill during other manual tasks such as drinking, eating, shaving/makeup application or computer work (Sheehy and Marsden, 1982; Jedynak et al., 2001).

The etiology and pathophysiology of WC is still unclear but there are several hypotheses to explain the underlying processes. Hallett (2006) defined three general physiological mechanisms (1) Loss of cortical inhibition was found in intra-cortical stimulation studies performed in patient with WC (Nakashima et al., 1989; Panizza et al., 1990; Chen et al., 1997; Sohn and Hallett, 2004; Quartarone et al., 2006; Torres-Russotto and Perlmutter, 2008); (2) Abnormal plasticity of the sensorimotor cortex may result from over-use as suggest by monkey experiments (Byl et al., 1996; Torres-Russotto and Perlmutter, 2008; Lin and Hallett, 2009); (3) Psychophysical tests of sensory perception revealed sensory dysfunction in patients with WC (Bara-Jimenez et al., 1998; Molloy et al., 2003; Lerner et al., 2004; Garraux et al., 2004). In addition, theories emphasizing behavioral aspects point to a role of maladaptive control strategies in the genesis of WC (Mai, 1996; Baur et al., 2009b)

In WC deteriorated handwriting fluency is associated with excessive forces that are frequently combined with abnormal writing posters of fingers, wrist, elbow, and shoulder (Sheehy and Marsden, 1982; Mai and Marquardt, 1994; Schneider et al., 2010; Hermsdörfer et al., 2011). Several studies measured the finger forces produced during handwriting, and reported that the force exerted by the pen tip onto the writing surface (pen tip force) is elevated in patients with WC compared to healthy controls (Siebner et al., 1999; Schenk and Mai, 2001; Zeuner et al., 2005, 2007; Chakarov et al., 2006; Baur et al., 2006, 2009a,b; Schneider et al., 2010; Hermsdörfer et al., 2011). In addition, grip force, produced by the fingers against the pen barrel, were clearly increased in WC patients during writing (Baur et al., 2006; Schneider et al., 2010; Hermsdörfer et al., 2011). Both measures of finger force were found to be sensitive to muscular hyperactivity in WC patients and provided additive information on the individual disturbance pattern (Schneider et al., 2010; Hermsdörfer et al., 2011).

Since patients with dystonic/complex writer's cramp report additional deficits in non-writing fine motor tasks it is tempting to objectively investigate their manual performance. Object manipulation tasks seem particularly well suited since they have been extensively used in studies of sensorimotor and cognitive control strategies in healthy humans as well as in studies analyzing the consequences of brain damage on manual functions (Flanagan et al., 2006; Hermsdörfer, 2009; Nowak and Hermsdörfer, 2005). For example, measurements of finger forces during grasping and lifting of a weight revealed that healthy subjects adjust their grip force precisely to the weight and other characteristics of the object (Johansson and Westling, 1884; Johansson, 1996; Flanagan and Johansson, 2002). Clinical studies showed that the precise control of grip force during object lifting was disturbed in neurological diseases such as basal ganglia disorders (Fellows et al., 1998; Nowak and Hermsdörfer, 2005), stroke (Hermsdörfer et al., 2003; Raghavan et al., 2006), and cerebellar diseases (Fellows et al., 2001; Brandauer et al., 2008).

Another sensitive paradigm in studies of object manipulation was based on the measurement of grip forces during the movement of grasped objects. Continuous vertical movements generate time-varying acceleration-dependent inertial loads that add to or subtract from the gravitational load. Healthy subjects precisely compensated the resulting load profile by time-synchronous grip force modulations (Flanagan and Wing, 1995). However, patients with CNS diseases showed impaired grip force/load force coordination in this task (Hermsdörfer et al., 2008; Brandauer et al., 2010).

In these studies, healthy subjects used economical grip forces with small safety margins to prevent the object from slipping (Johansson and Westling, 1884; Johansson, 1996), whereas grip forces were almost invariably increased in patients with CNS disease.

The lifting task was tested in patients with writer's cramp. Patients used excessive grip force levels in relation to load force levels and grip forces in patients were increased compared to healthy controls (Odergren et al., 1996; Serrien et al., 2000; Schenk and Mai, 2001; Nowak et al., 2005b). In particular, Odergren et al. (1996) used lifting tasks with variations of the order of weight and found increased grip force levels in the static phase of lifting. The data of Serrien et al. (2000) confirmed deficits in grip force scaling while performing a drawer manipulation task. Odergren et al. (1996) and Serrien et al. (2000) concluded on the basis of their findings that disturbed sensorimotor processing is the cause for grip force deficits in WC patients. However Schenk and Mai (2001) investigated 22 WC patients and did not find a functional link between severity of deficits during handwriting and pen forces during handwriting as well as grip force during lifting an object. (Nowak et al., 2005a,b) observed increased grip force while grasping and lifting of a cylindrical object in patients with focal dystonia (writer's cramp, musician's cramp) that rapidly decreased during repeated lifts, and concluded that elevated grip forces is more a pre-learned phenomenon than the primary disorder.

These previous studies of patients with WC did not directly relate grip force production in non-writing tasks to grip force deficits during handwriting. This is however particularly interesting if focal dystonia is supposed to spread from writing disturbances to other fine motor tasks. Therefore, we quantified motor performance during handwriting and during two object manipulation tasks in a sample of patients with WC and in control subjects. Handwriting performance was registered using a graphic tablet and a force sensor matrix that registered the grip force in arbitrary types of pen grip (see Section 2 and Hermsdörfer et al., 2011). Object manipulation skills were assessed during grasping and lifting of boxes and during cyclic up-and-down movements of a grasped manipulandum. We were particularly interested in the grip forces exerted during both tasks, and in the relationship between these two grip forces and the grip force produced during hand writing. While the previous studies investigated only the lifting task in patients with WC, the cyclic task may closer match the demands during hand writing since the grip force has to be continuously modulated according to the varying dynamic loads. If grip force increases in writer's cramp generalise from handwriting to other fine motor tasks, increased forces during object manipulation have to be expected in those patients that used exaggerated forces during handwriting. Thus, correlations between the different grip forces are expected. If, on the contrary, WC is task-specific, no force increase during non-writing task and no corresponding correlation may be detected. It is conceivable that the outcome depends on the type of WC. Patients with simple and with dystonic/complex WC were therefore separated into two groups.

In addition to grip forces, sensorimotor integration and grip force coordination were evaluated in the object manipulation task. Sensorimotor integration was assessed as the ability to adapt forces to an unpredictable change of the weight of the lifted object (Johansson and Westling, 1988) and grip force coordination was quantified as the precision of grip force modulation according to load variations in the cyclic movement task (Flanagan and Wing, 1995). Since comparable basic sensorimotor skills in non-writing tasks have been shown to be preserved in patients with WC (Schenk and Mai, 2001; Nowak et al., 2005b; Hermsdörfer et al.,