

The role of the ipsilesional side in the rehabilitation of post-stroke subjects

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Abstract

Most stroke lesions occur in the middle cerebral artery territory, presenting a high probability of damage of pathways with predominant ipsilesional disposition, mainly related to postural control. Despite the high probability of bilateral postural control dysfunction based on neuroanatomical fundamentals, both research and clinical rehabilitation involving stroke subjects have been focused on contralesional side (also named affected side) impairments, while ipsilesional side (also named non-affected side) impairments have been attributed to an adaptive strategy.

This paper aims to present a critical understanding about the state-of-the-art that sustains the hypothesis that stroke subjects with middle cerebral artery territory lesion at the subcortical level show an atypical behaviour in the ipsilateral side associated with the lesion itself and the possible implications.

Keywords: Stroke; Ipsilesional side; Postural control; Rehabilitation.

1- Introduction

Epidemiological data show that most stroke subjects have a lesion in the middle cerebral artery territory (Mohr et al., 2004) at a subcortical level (Crafton et al., 2003; Schiemanck et al., 2006), which is why there is a high probability of an injury affecting the corticoreticular connection. Through this connection, the cerebral cortex, mostly the Brodmann's area 6 including the pre-motor cortex and the supplementary area, ensures the interdependence between postural control and movement function (Rothwell, 2009; Rothwell, 2012). These neuroanatomical and functional foundations explain the high probability of bilateral postural control impairment in subjects with stroke in subcortical areas and movement failure in the contralesional side (also named affected side) predominantly related to corticospinal system injury. In fact, the role of the reticular system over both sides of the body as to postural tone recruitment and modulation (Schepens et al., 2004) justifies the analyses of postural control function in both sides of the body in all motor tasks, and in all populations with or without pathology.

Although this line of reasoning is supported by neuroscientific knowledge, the research involving stroke subjects has given little attention to the comprehension of the behaviour of the ipsilesional side, usually referred to as the non-affected side (Hall et al., 2011; Lamontagne et al., 2002; Lamontagne et al., 2000; Milot et al., 2006; Peterson et al., 2010). Although some authors have already reported neuromotor dysfunctions in the ipsilesional limbs when compared to healthy controls (Hall et al., 2011; Lamontagne et al., 2002; Lamontagne et al., 2000; Milot et al., 2006), they explained the dysfunction as a compensatory strategy rather than as a consequence of the lesion (Higginson et al., 2006; Lamontagne et al., 2002; Lamontagne et al., 2000).

In relation to this issue, it is important to present the state-of-the-art that sustains the hypothesis that stroke subjects with lesion at the middle cerebral artery territory at a subcortical level show an atypical behaviour in the ipsilesional side associated with the lesion itself and to discuss the possible implications.

2- Postural control dysfunction in the ipsilesional side

To properly study the atypical behaviour associated with postural control dysfunction in the ipsilesional side it is important to select functional tasks that demand strong postural control. The sit-to-stand-to-sit and walking are good examples of this type of task (de Souza et al., 2011; Dehail et al., 2007; Galli et al., 2008; Hase et al., 2004)

since they involve the coordination of joints along the kinematic chain to keep the centre of mass within the safe limits of the body's base of support (Freitas et al., 2009; Jacobs, 1997; Kiemel et al., 2008; Morasso et al., 1999; Nicholas et al., 1998; van der Kooij et al., 1999). Additionally, the lower limbs must be coordinated to provide support and stability (Sousa et al., 2013b), being recognised by the central nervous system as one functional unit. The study of tasks involving this functional unit enables identifying any atypical behaviour, since it depends on the role of the reticulospinal system in interlimb regulation (Schepens et al., 2004). Moreover, the study of these tasks must focus the sub-phases with higher postural control demand, i.e. the initial phase of sit-to-stand and stand-to-sit (Silva et al., 2012b; Silva et al., 2012c), middle stance (Silva et al., 2012d; Sousa et al., 2012a), double support (Silva et al., 2015; Sousa et al., 2013a; Sousa et al., 2013b) and gait initiation (Sousa et al., 2015a, 2015b).

The above-mentioned sub-phases are highly demanding from a postural control perspective as they require the modulation of ankle plantar flexors to adjust their tension/length relationship, without losing the antigravity postural control. Several authors have highlighted the importance of the information provided by type II (Maupas et al., 2004) and Ib fibre groups of ankle plantar flexors on postural control during locomotion (Faist et al., 2006; Knikou, 2008). In cases of central nervous system lesion, like stroke, the plantar flexor muscles are more prone to activation failure than the proximal muscles (i.e. quadriceps) (Klein et al., 2010). Specifically, the behaviour of the soleus as a postural muscle may reveal postural control dysfunction more evidently, since uniarticular muscles are thought to be more affected by central influences than by peripheral influences (Kautz et al., 2005). Based on the above, the soleus muscle could be expected to reflect more accurately the postural control dysfunction as a result of a possible lesion of the cortical-reticular system. Changes in the activation timing of the soleus and tibialis anterior muscles during sit-to-stand and stand-to-sit in post-stroke subjects support this notion (Silva et al., 2012b).

Similarly to what was observed during the first phase of sit-to-stand and stand-to-sit, stereotyped activity patterns have been demonstrated during the first phase of gait initiation (Brunt et al., 1991; Brunt et al., 1999; Crenna et al., 1991; Elble et al., 1994; Fiolkowski et al., 2002; Shapiro et al., 1981). The inhibition of the tonically active soleus followed by the activation of the tibialis anterior early in gait initiation (Crenna et al., 1991; Elble et al., 1994; Jian et al., 1993) enable the backward displacement of the centre of pressure (Brunt et al., 1991; Crenna et al., 1991), contributing to postural stability

(Massion, 1992; McIlroy et al., 1999), as well as the optimum generation of momentum at the end of the first step to reach the steady-state gait (Lepers et al., 1995). Recent studies have demonstrated that subcortical post-stroke subjects present failure in modulating the soleus timing in both contralesional and ipsilesional limbs (Sousa et al., 2015a), which is associated with a decreased backward displacement of the centre of pressure (Sousa et al., 2015a, 2015b). This bilateral impairment reduces stability and performance in gait initiation. Considering that muscle activation's timing on postural adjustments depends on the corticoreticular connection, these findings suggest that this atypical behaviour is related to the lesion. The evidence demonstrating that the atypical behaviour of the ipsilesional plantar flexors changes according to their role during gait double support strengthens this association (Silva et al., 2015). Walking is the task where, in a rhythmic way, muscle roles change automatically. During double support, the trailing limb's soleus muscle provides body support (McGowan et al., 2008) while the gastrocnemius medialis is associated with forward progression (Anderson et al., 2003; Hall et al., 2011; Neptune et al., 2001). The leading limb's ankle dorsiflexors attenuate the initial contact, being important in weight acceptance (Winter, 1983). In fact, the hypothesis that the neuronal injury is the cause for the ipsilesional limb's atypical behaviour instead of a compensatory mechanism is supported both by the fact that the performance of ipsilesional plantar flexors, in stroke subjects, changes according to the limb's position (Silva et al., 2015) and by the fact that, during step-to-step transition, the contralesional limb is influenced by the ipsilesional limb and not the opposite (Sousa et al., 2013a). This also reinforces the evidence that the muscles associated with the ventral-medial systems' activity may present a more pronounced atypical behaviour while assuming an agonist role.

The previously exposed opens the discussion as to the connection between some efferent systems and specific muscles. The close relation between ventral-medial systems and the activity of postural muscles like the soleus (Horn, 2004) may justify the selection of this muscle to assess the output of ventral-medial efferent systems over the lower limb. In fact, the large contribution from group Ib fibres to the amplitude modulation of the soleus muscle activity during weight-bearing activities (Mazzaro et al., 2006) and the strong role of reticulospinal pathways on group II fibres (Davies et al., 1994; Marchand-Pauvert et al., 2005) highlight the connection between this muscle and the reticular system. The assessment of muscle activity considering that movement's capacity also depends on postural control ability demands an integration of both limbs' evaluation in the rehabilitation of post-stroke subjects.

3- Implications for practice and concluding remarks

For a long time, the ipsilesional side has been considered the non-affected side and therefore the reference to identify the dysfunction of the contralesional side. This reference has been used both in the clinical practice and in research. This approach may have negative consequences in the decision-making process, as it: 1) limits the identification of a possible ipsilesional impairment related to postural control; 2) limits the gains in the rehabilitation process, since movement failure of the contralesional side is also related to ipsilesional postural control dysfunction (gait initiation is an example of this pre-requisite); 3) compromises the inter-limb coordination necessary for most functional activities, particularly during walking, as strategies are focused on the contralesional limb's behaviour only.

There is evidence pointing that post-stroke subjects with lesion in the middle cerebral territory present impairments also in the ipsilesional limbs and, because of this, both limbs should be considered along the rehabilitation program, as both interfere with movement performance and postural control regulation.

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