

Asymmetry of Movement and Postural Balance and Underlying Functions in Humans

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Human movements and posture often show lateral asymmetries. Although symmetry is not systematically observed between two limbs, its presence is likely to influence motor and postural performance and the risk of injury and falls in sportspeople, healthy, elderly, and frail subjects during professional, sports and leisure activities, as well as activities in day to day life [1–3]. A systematic search for possible inter-limb asymmetry in the context of the optimization of motor performance or the rehabilitation of functional abilities can be undertaken. Inter-limb symmetry or asymmetry may occur as a function of motor experience (e.g., high versus low), the nature of movements (e.g., specialized versus non-specialized), the environmental context (e.g., easy versus difficult motor tasks), individual or intrinsic factors (e.g., proprioception, hemispheric laterality, motor output) and the limb dominance effect. The finer details of motor and postural symmetry or asymmetry have not yet been fully identified in terms of information perception, central integration and movement command and control [4]. In addition, the neural mechanisms involved are also not fully understood at the different neurological levels (peripheral, spinal, subcortical and cortical). Therefore, exploratory research is needed in order to understand symmetry or asymmetry in terms of human movement and posture. This Special Issue, “Neurosciences, Neurophysiology and Symmetry”, includes six papers that provide some answers to these questions, focusing mainly on asymmetry in human movement and posture.

The first paper, by Barbara Dobies-Krześniak et al. [5], tests the hypothesis that functional laterality features are associated with scoliosis incidence (radiologically confirmed as idiopathic scoliosis). Side dominance was determined by the lateral preference inventory. The direction, strength and consistency of lateral dominance were evaluated. Lateralization analysis showed some trends, but the results obtained were not statistically significant. Thus, the relationship between scoliosis and laterality may not be a simple causal relationship, and needs further investigation.

The second paper is based on the kinematic analysis of lower limb joint asymmetry during gait in people with multiple sclerosis [6]. The majority of people with multiple sclerosis (pwMS), report lower limb motor dysfunctions, which may affect postural control, gait and a wide range of daily activities. While it is quite common to observe a differing impact of the disease on the two limbs (i.e., one of them can be more affected), less clear are the effects of such asymmetry on gait performance (kinematic and spatio-temporal parameters with eight-camera motion capture system). Based on cyclogram orientation and trend symmetry, the results showed that pwMS exhibit significantly greater asymmetry in all three joints (hip, knee, ankle) than unaffected individuals. Moreover, the same parameters were sensitive enough to discriminate individuals of different disability levels. With few exceptions, all the calculated symmetry parameters were found to be significantly correlated with the main spatio-temporal parameters of gait and the EDSS (Expanded Disability Status Scale) score. In particular, large correlations were detected between Trend Symmetry and gait speed and between trend symmetry and EDSS score. Such results suggest not only that MS is associated with significantly marked interlimb asymmetry



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during gait, but also that such asymmetry worsens as the disease progresses and that it has a relevant impact on gait performances.

Based on the fact that the current literature shows no consensus regarding the difference between the dominant leg (D-Leg) and the non-dominant leg (ND-Leg) in terms of postural control, the third paper deals with the effects of limb dominance on postural balance in sportsmen practicing symmetric and asymmetric sports [7], the hypothesis being that the lack of consensus could stem from motor experience (i.e., symmetric or asymmetric motricity) and/or the physiological state induced by physical exercise. The study by Kadri et al. [7] aimed to investigate the acute effects of fatiguing exercise on postural control when standing on the D-Leg and the ND-Leg in athletes practicing symmetric (SYM) and asymmetric (ASYM) sports. Monopodal postural control was assessed for the D-Leg and the ND-Leg before and after the fatigue period (which consisted of repeating squats until exhaustion). A force platform was used to calculate the spatio-temporal characteristics of the displacements of the center of foot pressure (COP). A significant fatigue effect was observed in both groups on the D-Leg and the ND-Leg for all the COP parameters. There was a strong tendency ($p = 0.06$) between the ASYM and SYM groups on the D-Leg, concerning the relative increase in the COP velocity in the frontal plane after the fatigue period. The fatigue condition disturbed postural control in both the SYM and ASYM groups on the D-Leg and ND-Leg. This disturbing effect related to fatigue tends to be more marked in athletes practicing asymmetric sports than in athletes practicing symmetric sports on the D-Leg. Effects related the nature of sports (SYM and ASYM) and muscle fatigue need to be confirmed (or negated) by future studies.

The fourth paper is innovative and is entitled “From Neural Command to Robotic Use: The Role of Symmetry/Asymmetry in Postural and Locomotor Activities” [8]. This article deepens a reflection on why and how symmetry/asymmetry affects the motor and postural behavior from the neural source, through uterine development and child maturation, and how the notion of symmetry/asymmetry has been applied to the design and control of walking robots. The concepts of morphology and tensegrity are also presented, to illustrate how the biological structures have been used in both sciences and arts. The development of the brain and the neuro-fascia-musculoskeletal system seems to be relatively symmetric from the beginning of life through to complete maturity. The neural sources of movements (i.e., central pattern generators) are able to produce either symmetric or asymmetric responses to accommodate environmental constraints and task requirements. Despite the fact that human development is mainly symmetric, asymmetries regulate neurological and physiological development. Laterality and sports training could affect the natural musculoskeletal symmetry. The plasticity and flexibility of the nervous system allows it to adapt and compensate for environmental constraints and musculoskeletal asymmetries in order to optimize the postural and movement control. For designing humanoid walking robots, symmetry approaches have been mainly used to reduce the complexity of the online calculation. Applications in neurological retraining and rehabilitation should also be considered.

The following two articles do not deal specifically with motor and postural asymmetries, but focus more broadly on cerebral asymmetries and functional abilities. The paper by Van Vuuren et al. [9] is based on the fact that neonatal and adult strokes are more common in the left than in the right cerebral hemisphere in the middle cerebral arterial territory, and adult extracranial and intracranial vessels are systematically left-dominant. The aim of the research reported here was to determine whether the asymmetric vascular ground plan found in adults was present in healthy term neonates. A new transcranial Doppler ultrasonography dual-view scanning protocol, with concurrent B-flow and pulsed wave imaging, acquired multivariate data on neonatal middle cerebral arterial structure and function. This study documents systematic asymmetries in the middle cerebral artery origin and distal trunk of healthy term neonates for the first time, and identifies commensurately asymmetric hemodynamic vulnerabilities. A systematic leftward arterial dominance was found in the arterial caliber and cortically directed blood flow. The endothelial wall shear

stress was also asymmetric across the midline, and varied according to vessels' geometry. They conclude that the arterial structure and blood supply in the brain are laterally asymmetric in newborns. Unfavorable shearing forces, which are a by-product of the arterial asymmetries described here, might contribute to a greater risk of cerebrovascular pathology in the left hemisphere.

The last paper dealt with the neurological asymmetry of self-face recognition [10]. While the desire to uncover the neural correlates of consciousness has taken numerous directions, self-face recognition has been a constant in attempts to isolate aspects of self-awareness. The neuroimaging revolution of the 1990s brought about systematic attempts to isolate the underlying neural basis of self-face recognition. These studies, including some of the first fMRI (functional magnetic resonance imaging) examinations, revealed a right-hemisphere bias for self-face recognition in a diverse set of regions, including the insula, the dorsal frontal lobe, the temporal parietal junction, and the medial temporal cortex. This systematic review provides confirmation of these data (which are correlational), which were provided by TMS (transcranial magnetic stimulation) and patients in which the direct inhibition or ablation of right-hemisphere regions leads to a disruption or absence of self-face recognition. These data are consistent with a number of theories, including a right-hemisphere dominance for self-awareness and/or a right-hemisphere specialization for identifying significant social relationships, including to oneself.

In conclusion, asymmetries of motor and postural functions and many other organic functions in humans are likely to be observed at any age, in healthy and pathological subjects, and deserve to be fully explored in order to better anticipate and (possibly) prevent them. In this ambition, scientific research in this field is still in its infancy.

Conflicts of Interest: The author declares no conflict of interest.

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