Neuroscience and Biobehavioral Reviews 72 (2017) 129–152

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

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

Plasticity of the postural function to sport and/or motor experience

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ARTICLE INFO

Article history:
Received 6 July 2016
Received in revised form 27 October 2016
Accepted 15 November 2016
Available online 26 November 2016

Keywords:
Physical activities
Sport activities
Motor experience
Motor expertise
Postural balance
Proprioception
Visual information
Vestibular information
Somatosensory afferences
Postural performance
Postural strategy
Postural adjustment

ABSTRACT

This review addresses the possible structural and functional adaptations of the postural function to motor experience. Evidence suggests that postural performance and strategy evolve after training in inactive subjects. In trained subjects, postural adaptations could also occur, since elite athletes exhibit better postural performance than, and different postural strategy to sub-elite athletes. The postural adaptations induced are specific to the context in which the physical activity is practiced. They appear to be so specific that there would be no or only a very slight effect of transfer to non-experienced motor tasks (apart from in subjects presenting low initial levels of postural performance, such as aged subjects). Yet adaptations could occur as part of the interlimb relationship, particularly when the two legs do not display the same motor experience. Mechanistic explanations as well as conceptual models are proposed to explain how postural adaptations operate according to the nature of physical activities and the context in which they are practiced as well as the level of motor expertise of individuals.

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http://dx.doi.org/10.1016/j.neubiorev.2016.11.015

1. Introduction

Posture and balance control are fundamental in daily life in order to safely accomplish any kind of movement and motor task that involves the displacement of body segments or the whole body. Posture can be defined as the position of different body segments, and balance as the maintenance of the center of mass -COM- of the body above the base of support in order to avoid a fall. Thus, postural balance characterizes the ability to maintain a particular segmental organization without falling. Efficient postural balance not only reduces the risk of body imbalance, fall, and subsequent injuries but also contributes to optimizing motor performance (Horak, 2006; Delbaere et al., 2006; Stone et al., 2015). In this respect, the ability to ensure postural balance depends on internal body representation (i.e. body representation in space) which is developed with sensory inputs and is based on body geometry (segmental organization), kinetics (ground reaction force) and body orientation and vertical perception (subjective verticality) cues (Paillard, 2012) (Fig. 1). Postural balance is organized in hierarchical and stereotypic patterns and requires the central integration of vestibular, visual, cutaneous and proprioceptive inputs as well as the motor command of antigravity muscles (Massion, 1994). The postural function chronologically includes sensory, central and motor components (Fig. 2).

The efficiency of postural balance can be quantitatively considered by evaluating the movement of the COM, the center of pressure (COP) of the foot and body segments but also by measuring electromyographic (EMG) activities (with accelerometry, goniometry, kinetic, kinematic, and EMG techniques). The qualitative analysis consists of describing how postural balance is organized in relation to mechanical (segmental organization) and neurophysiological (sensory contributions and their integration and motor command) aspects. Postural balance can be characterized in terms of performance according to the postural condition under consideration. Postural performance refers to the ability to maintain body balance in challenging postural conditions (e.g. a stance classed as a handstand, monopedal dynamic stance) or the ability to minimize continuous body sway in more conventional postural conditions (e.g. bipedal quiet stance) (Paillard and Noe, 2015). Postural strategy can be defined on the basis of the spatial and temporal organization of different body segments as well as the extent and order of recruitment of different muscles activated (Paillard and Noe, 2015). These authors specified that the different sensory sensors involved in postural regulation as well as the weight of different sensory information and/or the preferential involvement of different neuronal loops can also contribute to describing postural strategy.

Many intrinsic factors impact postural balance. These factors include age (with the advancement of age the postural function undergoes involution, with the child's development -i.e. growth and maturation- the postural function is improved), morphology (weight and height negatively affect postural balance), physiological/physiopathological state (in healthy subjects e.g., muscle typology and neuromuscular characteristics influence the motor output of the postural function; in pathological subjects e.g., some neurological pathologies and pathologies of the locomotor system affect sensory inputs and/or their integration and/or motor output) and psychological/psychiatrical state (in healthy subjects e.g., the visual field dependence can influence the contribution of sensory information; in pathological subjects e.g., some pathologies affecting the cognitive function disturb postural balance) (Assaiante and Amblard, 1995; Slaboda et al., 2009; Steinmetz et al., 2010; Johnson and Woollacott, 2011; Ku et al., 2012; Suttanon et al., 2013; Maitre et al., 2013; Dirnberger and Jahanshahi, 2013; Zaback et al., 2015; Rinalduzzi et al., 2015; Miller et al., 2015). In pathological subjects, rehabilitation programs can reduce or reverse postural impairments through physical, cognitive, orthopedic and other interventions, combined or not (McCaskey et al., 2015; Khanal et al., 2016; Subramaniam et al., 2014). In healthy young subjects, the main factor which is likely to durably modify their postural balance is characterized by motor experience, i.e. all physical activities including domestic and leisure physical activities as well as sport and exercise (for a definition of these terms, see Khan et al., 2012).

Although acute physical activity can disturb postural balance by degrading the effectiveness of sensory inputs and motor output of the postural function (for a review, see Paillard, 2012), chronic/regular physical activity improves postural balance by inducing positive functional adaptations to the postural function (for reviews, see Hrysomallis, 2011; Kiers et al., 2013; Lesinski et al., 2015a,b; Behm et al., 2015). There is a relationship between postural performance and athletic performance in healthy persons who regularly practice physical and/or sport activities (Hrysomallis, 2011; Kiers et al., 2013). Moreover, regular balance or strength exercises improve postural balance (Behm et al., 2015; Lesinski et al., 2015a,b; Kümmel et al., 2016) according to dose-response relationships (Lesinski et al., 2015a,b). Taken together, these