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# A scoping review on anticipatory muscular activations during movement-to-movement transitions

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## 1. Introduction

Performing a whole-body movement relies on a complex coordination controlled by the Central Nervous System (CNS). Particularly, the CNS ensures that the appropriate movement is executed while the whole-body stability is maintained. Because of this duality in the control of whole-body movement, it remains unclear how the muscle contractions – and the underlying motor commands – specifically contributes to either the execution of the movement, the control of the stability, or both of them.

Motor transitions can be defined as motor actions executed between two steady-states, when the CNS aims to change the velocity of the whole-body Centre of Mass (Tisserand et al. 2015). According to this definition, three types of transitions can be identified: (i) posture-to-posture, (ii) posture-to-movement or movement-to-posture, and (iii) movement-to-movement. Transitions are commonly used to study the interactions between movement and stability, because the quick change of segment momentum challenges the whole-body stability (Jian et al. 1993).

Internal models proposed that the CNS can predict the future state of the whole-body based on its actual state and an efferent copy of the motor command (Wolpert and Kawato 1998). Hence, when the movement constraints are known (i.e. in a voluntary movement), the CNS can program anticipatory muscular activations (i.e. that begin before movement onset) to create favorable biomechanical conditions for movement execution. Among these anticipatory processes, Anticipatory Postural Adjustments (APAs) were identified in two types of transition. In both posture-to-posture (e.g. arm-raising) and posture-to-movement (e.g. gait initiation, gait termination or squat jump), anticipatory muscular activations and/or inhibitions were found in ankle flexors and extensors, mono-articular muscles (Massion 1992; Jian et al. 1993; Le Pellec and Maton 1999), suggesting two mechanical roles: (i) counteract the forthcoming postural perturbation and (ii) create a torque initiating or terminating

the movement. From these observations, a model for the anticipatory processes has been proposed with two parallel but distinct motor commands, associated with stability and movement: postural and focal (Massion 1992). Because most studies on self-initiated movements showed that APAs are time-locked to the focal movement, scaled with the magnitude of motor action, perturbation, and degree of initial instability (Aruin 2002), the parallel model predicts that the postural action should be achieved before the onset of the focal one (Massion 1992).

While predictions from the parallel model seem accurate to explain the mechanical role of anticipatory muscular activations for posture-to-posture and posture-to-movement transitions, they have never been explicitly tested for a movement-to-movement one. Muscular activations preceding important mechanical constraints have been investigated in transitions such as Drop-Jump (DJ) and change of direction, but were never called APAs (Horita et al. 2002; Leukel et al. 2011; Helm et al. 2020). Thus, the mechanical role of anticipatory muscular activations during movement-to-movement transitions remains unclear.

The aim of this scoping review was to collect insights about the anticipatory muscular activations reported in movement-to-movement transitions to clarify their mechanical role. We focused only on DJ because it can be viewed as a combination of two successive motor tasks (landing and jumping) that imply anticipatory muscular activations playing two opposite roles (landing and propulsion). Also, DJ is repeatable, external mechanical constraints are easy to control, and incertitude can be induced to participants (Helm et al. 2020).

## 2. Methods

One person performed the electronic search in January 2022 in PubMed and Science Direct databases. Logical expressions for the search included ('pre-act\*' OR 'anticip\*') AND ('musc\*' OR 'electromyo\*') AND ('drop-jump' OR 'drop jump' OR 'deep jump'). The search was based on titles, keywords, and abstracts. Exclusion criteria were: study on animals, no electromyographic recording, pathological subjects, longitudinal studies, visual analysis, material testing.

## 3. Results and discussion

A total of 24 primary articles were found (19 in PubMed and 5 in Science Direct) of which 17 articles were removed because they met exclusion criteria. As a result, 7 articles were analyzed and 4 of them will be discussed here, because of major insights.

During a DJ, the transition phase enables the body to vertically decelerate and then accelerate in the opposite direction to jump. The anticipatory phase is generally identified as the air-time before landing. Anticipatory muscular activation amplitudes are consistent between trials, and larger in DJ than in landing (Leukel et al. 2011). These amplitudes also increase with the drop-height, but remain stable in timing (Helm et al. 2020). These results show that DJ anticipatory muscular activations are adapted to both mechanical constraints and movement intentions, suggesting the CNS centrally programs a DJ as a specific sequence of movements, and anticipate the mechanical consequences of this sequence as a whole.

Because DJ is programmed as a sequence involving two movements, different strategies can be used: increase the ground contact time (GCT), by flexing all lower limb joints, to favor the energy absorption at landing, and increase impulsion time; or reduce the GCT, by increasing anticipatory activations and stiffening the knee, to favor energy restitution (Horita et al. 2002; Hobara et al. 2009). These strategies seem to be chosen according to the objective of the task, the external constraints, and the athlete qualities. These results suggest that anticipatory muscular activity can be predictively modulated to adjust the muscle-tendon stiffness according the constraints of the motor task.

These observations mainly come from measures on mono-articular muscles and the question remains open about their functional role. Indeed, during DJ, the same mono-articular muscles (mainly Soleus and Vastus) are documented to be both absorber, during the landing phase, and prime movers, during the push-off phase (Leukel et al. 2011). The functional roles for these two phases are opposite, yet performed by the same muscles. This questions the potential parallel model proposed by Massion (1992) for APAs with separated focal and postural muscular activations.

Finally, the functional role of anticipatory activations in bi-articular muscles is not well-documented. Previous studies suggested that gastrocnemius and biceps femoris could play different roles during movement: either as global stiffness regulators when they are co-contracted with mono-articular antagonists, or in transferring power from proximal to distal segments (Cleather et al. 2015). More research is necessary to disentangle their role during a movement-to-movement transition. Recent methodology quantifying muscle length (Retailleau and Colloud 2020) could be useful

to assess the mechanical role of their anticipatory activations.

#### 4. Conclusions

The parallel model provides insights to understand the anticipatory processes during posture-to-posture and posture-to-movement transitions, but has not been explicitly tested for movement-to-movement ones. DJ is a transition centrally programmed as a sequence, with anticipatory activations depending on both landing and jumping tasks. Investigating the functional role of muscles involved in this transition will help understand how the opposites roles are managed, and will complement our understanding of the movement-stability coordination by the CNS.

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