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# Shoulder muscles recruitment during a power backward giant swing on high bar: A wavelet-EMG-analysis

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ABSTRACT

This study aimed at determining the upper limb muscles coordination during a power backward giant swing (PBGS) and the recruitment pattern of motor units (MU) of co-activated muscles. The wavelet transformation (WT) was applied to the surface electromyographic (EMG) signal of eight shoulder muscles. Total gymnast's body energy and wavelet synergies extracted from the WT-EMG by using a non-negative matrix factorization were analyzed as a function of the body position angle of the gymnast. A cross-correlation analysis of the EMG patterns allowed determining two main groups of co-activated muscles. Two wavelet synergies representing the main spectral features (82% of the variance accounted for) discriminated the recruitment of MU. Although no task-group of MU was found among the muscles, it appeared that a higher proportion of fast MU was recruited within the muscles of the first group during the upper part of the PBGS. The last increase of total body energy before bar release was induced by the recruitment of the muscles of the second group but did not necessitate the recruitment of a higher proportion of fast MU. Such muscle coordination agreed with previous simulations of elements on high bar as well as the findings related to the recruitment of MU.



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## 1. Introduction

The biomechanical approach of the power backward giant swing (PBGS) around the high bar showed that the interaction between the gymnast's energy (kinetic energy + potential energy) and the bar (elastic energy) resulted in a significant increase of the energy of the gymnast when approaching the bar release. This increase in energy of the gymnast was due to elastic properties of the bar and muscular actions at the shoulders and hips, which allowed dismounts and release-regrasp elements (Arampatzis & Brüggemann, 1998, 1999, 2001). The literature allowed to certify that the muscular actions of the upper limbs, especially around the shoulder joints, were the most important in achieving a PBGS on high bar. The ascending phase between the vertical axis and the bar release corresponded to the phase where the shoulder joint was the most solicited (Arampatzis & Brüggemann, 1998; Holvoet, Lacouture, Duboy, Junqua, & Bessonnet, 2002; Irwin & Kerwin, 2007). However, the upper limbs muscles activations during elements on high bar are currently lacking in the scientific literature. Solely flexor and extensor muscles of the wrist were investigated with surface electromyography (EMG) to determine a potential effect of different hand guards during giant swing on high bar (Neal, Kippers, Plooy, & Forwood, 1995).

The human shoulder joint complex can be seen as a "perfect compromise between mobility and stability" (Veeger & van der Helm, 2007). Due to a closed chain mechanism, the mobility of the shoulder complex is mainly attributed to those of the gleno-humeral joint and scapulothoracic-gliding plane and to a lesser extent to the one of the sterno-clavicular joint. Especially for the gleno-humeral joint, the lack of congruency of the articular surfaces makes the joint inherently instable. Stability is essentially dependent on capsule-ligamentous structures and the musculo-tendinous cuff (Culham & Peat, 1993). Thus, the shoulder muscles must manage two complementary tasks: to produce powerful torque for movement and to maintain the integrity of the shoulder joint complex. Overhead sports, in which high torque generation in extreme ranges of motion is needed, are privileged case studies to determine the shoulder muscles coordination and recruitment that allow ensuring this double task. There is a growing body of evidence that when a muscle performed different tasks under dynamic conditions (e.g., walking), the motor unit (MU) recruitment can differ to the well known Henneman size-principle (Henneman, 1957; Henneman, Somjen, & Carpenter, 1965). This concept of task groups of MU was initially proposed by Loeb (1985) and implies that pools of MU are selectively recruited for different kinematic conditions within a motor task (Hoffer et al., 1987). More recently, several studies also quantified the recruitment of pools of MU dependent on various kinematical and mechanical conditions from surface electromyography (von Tscharner & Goepfert, 2006; Wakeling, Pascual, Nigg, & von Tscharner, 2001; Wakeling & Rozitis, 2004; Wakeling, Uehli, & Rozitis, 2006). But, the ability to separate and quantify pools of slow and faster MUs directly from surface EMG is still controversial (Enoka et al., 2008; Farina, 2008; von Tscharner & Nigg, 2008), notably to the fact that the power spectrum of such signal is under influence of several confounding factors in addition to the recruitment pattern of slow and fast MUs. However, the combination of the wavelet transformation of the EMG signal and of a decomposition algorithm (such as principal component analysis) seemed to give a reliable processing to quantify the strategy of recruitment of slow or fast MUs (Hodson-Tole & Wakeling, 2009). Indeed, Wakeling et al. (2006) quantified the recruitment strategy of pools of MUs among different conditions of pedal speeds and loads in cycling and determined that the frequency shifts of the EMG signal due to the confounding factors were significantly lower than those due to the activation-deactivation of pools of MUs.

Therefore, this study analyzed the upper limb muscles coordination through surface EMG recording during a PBGS and aimed at determining the recruitment pattern of pools of MUs of muscles that were activated together. It was expected that a specific group of muscles was activated to ensure the stability of the shoulder joint complex and that another group provided the mobility of the shoulder joint complex, especially in the most demanding phase of the PBGS (i.e., the ascending phase before the bar release). It was also expected to quantify different recruitment patterns for pools of slow and fast MUs among all the recorded muscles, especially for those mainly activated for the mobility of the shoulder joint.