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Patterns of anterior and posterior muscle chain interactions during high performance long-hang elements in gymnastics

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ABSTRACT

In a prior study with high level gymnasts we could demonstrate that the neuromuscular activation pattern during the "whip-like" leg acceleration phases (LAP) in accelerating movement sequences on high bar, primarily runs in a consecutive succession from the bar (punctum fixum) to the legs (punctum mobile). The current study presents how the neuromuscular activation is represented during movement sequences that immediately follow the LAP by the antagonist muscle chain to generate an effective *transfer of momentum* for performing specific elements, based on the energy generated by the preceding LAP. Thirteen high level gymnasts were assessed by surface electromyography during high performance elements on high bar and parallel bars. The results show that the neuromuscular succession runs primarily from punctum mobile towards punctum fixum for generating the transfer of momentum. Additionally, further principles of neuromuscular interactions between the anterior and posterior muscle chain during such movement sequences are presented. The findings complement the understanding of neuromuscular activation patterns during rotational movements around fixed axes and will help to form the basis of more direct and better teaching methods regarding earlier optimization and facilitation of the motor learning process concerning fundamental movement requirements.

1. Introduction

In earlier publications (von Laßberg et al., 2009a, 2013) the "punctum fixum – punctum mobile model" was already introduced. This model refers to general principles of neuromuscular activation patterns for generating a "whip-like" acceleration of the most distal body segment during movements around fixed axes. The "punctum fixum" in the sense of this model is defined as the part of the body, which is fixed at the rotational axis, the "punctum mobile" is defined as the body segment being located most distant from the rotational axis. The model postulates that for an effective acceleration of the "punctum mobile" the "intersegmental neuromuscular onset succession" (INOS)[1] has to run principally from the "punctum fixum" (pfix) to the "punctum mobile" (pmob). According to this hypothesis, it could be demonstrated that the neuromuscular succession (INOS) of the anterior muscle chain of high level gymnasts for generating an effective leg acceleration during long hang elements on high bar, indeed, primarily runs from the bar (pfix) towards the legs (pmob), even if the temporal succession of the intersegmental *kinematic output* (closing of the leg-trunk angle and shoulder angle) runs inversely (von Laßberg et al., 2013). Fig. 1 outlines these patterns.

In contrast to the neuromuscular succession (INOS) to generate this preparatory *leg acceleration phase* (LAP), the aim of the *present* study was to investigate the neuromuscular succession (INOS) to *generate the subsequent transfer of momentum* and how the anterior and posterior muscle chain interact during such movement sequences.

Eventhough there are several publications concerning biomechanical aspects of long hang elements on high bar and on parallel bars (e.g. Arampatzis and Brüggemann, 1999, 2001; Arkaev and Succhilin, 2009; Bauer, 1983; Irwin and Kerwin, 2007; Tsuchiya et al., 2004; Yeadon and Hiley, 2000) and some very few publications concerning to electromyographic measurements (EMG) in gymnastics (e.g. Bernasconi et al., 2006; Medved et al., 1995; Frere et al., 2012), there do not exist publications (with exception of our own studies) concerning to principles of intersegmental neuromuscular coordination (e.g. INOS) during fundamental movement sequences of whole body rotations in sports.

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[1] For better readability this short-term "INOS" in brackets shall help to more clearly define what is meant exactly if other terms should be used.

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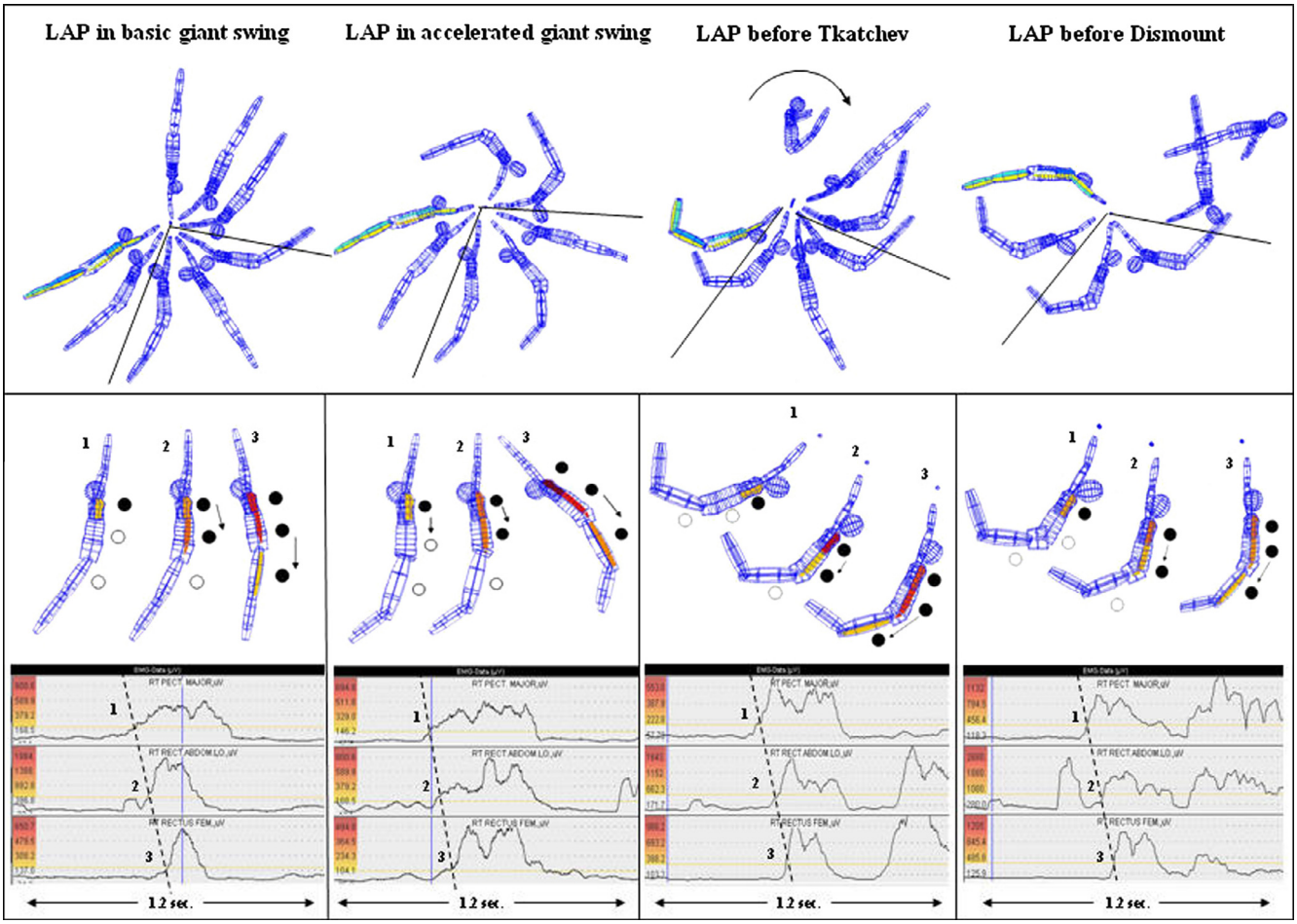

Fig. 1. Overview: Original data of the typical patterns of intersegmental neuromuscular onset succession from punctum fixum to punctum mobile for generating efficient whip-like "leg acceleration phases" (LAP) of different gymnastics elements on high bar (von Laßberg et al., 2013). These phases are marked by "whip like" acceleration from an "arched" to a "piked" position of the lower body and hips. The upper pictures demonstrate the complete elements, the sectors between the black lines approximately represent the sectors of the LAP. The pictures and EMG data below show the detailed neuromuscular onset succession for generating this whip-like leg acceleration (first plot: m. pectoralis mayor; second plot: m. rectus abdominis; third plot: m. rectus femoris). *Note for the LAP before dismount:* The activation of m. rectus abdominis *prior* to the measured onset time (dotted line) is an eccentric activation to stop the active hyperextension movement prior to LAP. So this is not a part of the LAP generating pattern.

With regard to practical apprenticeship of coaches in gymnastics some authors postulate the necessity of an efficient *transfer of momentum* in some specific elements (e.g. Bessi, 2010, pp. 210; Knirsch, 1983, pp. 345). However, no publications relate to this topic to verify the intersegmental coordination of neuromuscular activation (e.g. INOS) which is *necessary* to realize such momentum transfer phases (MTP) as efficient as possible.

Based on the results of a pilot study which led to the "punctum fixum – punctum mobile hypothesis" (von Laßberg et al., 2009a), it was postulated that for generating an *efficient transfer of momentum*, the neuromuscular onset succession (INOS) has to run the *opposite* direction as for generating an LAP (from punctum mobile back to punctum fixum). This hypothesis was based on the observation of specific intersegmental activation patterns between the anterior and posterior muscle chain during giant swings which show a *recurring activation* (INOS) of the posterior muscle chain after the leg acceleration, combined with a corresponding *deactivation* of the anterior muscle chain (Fig. 2). This led to the hypothesis that these specific patterns of agonist–antagonist interaction result in an actively induced deceleration of the legs with a succeeding transfer of momentum from the punctum mobile back to the punctum fixum.

This hypothesis was further underlined by the fact that during *accelerated giant swings* (marked by a strongly piked body position during the overswing of the bar; see Fig. 1) no such antagonist activation during the upswing phase was observed (von Laßberg et al., 2009a).

Based on these observations the following hypothesis was formulated: "For an effective *transfer of momentum* after acceleration of the punctum mobile, the intersegmental neuromuscular onset succession of the antagonist muscle chain has to run principally *from punctum mobile to punctum fixum*". In particular, this hypothesis will be considered within this study by further EMG measurements in a group of high level gymnasts (different participants as in the pilot study) and during further long hang elements which we assumed to be marked by the need of an effective momentum transfer phase after prior leg acceleration.

2. Methods

2.1. Procedure of the measurements

13 High level male gymnasts were measured by wireless surface electromyography (EMG) during the demonstration of different elements on high bar and parallel bars, all beeing assumed to be marked by an efficient MTP after a prior LAP.

The following elements were tested (Fig. 3): giant swings on high bar ($n = 50$); giant swings on parallel bars ($n = 21$); and