RELATION BETWEEN INITIAL MUSCLE LENGTH AND ELECTROMECHANICAL DELAY

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INTRODUCTION: Comparing the EMG of a muscle with the corresponding force-time-course, a distinct phase-shift can be detected between the electrical activity (EMG onset) and the mechanical response (force onset). This time shift is called motor time [11] or electromechanical delay (EMD) [1,7]. EMD has been found to be correlated to the maximal voluntary contraction (MVC) force, the rate of force development and the muscle fiber type composition [13].
For motion-analysis an exact knowledge of EMD can suggest important conclusions concerning the mechanical effectiveness of a particular muscle - e.g., the hamstrings (HS) in sprint running [10] - which becomes evident via the corresponding EMG. However, the exact value of EMD remains a factor of uncertainty. Recent results show an EMD of 24ms [4,6] for explosive MVCs of the HS in an optimal muscle length (OML). Therefore these values are distinctly under those previously determined for the hip flexor muscles, ranging between at least 32ms [9] and 118ms [5].
However, athletic movement normally starts in an initial muscle length (IML) which is not necessarily identical with OML. Previous publications comparing two or at the most three IML show both positive and negative relations to EMD. While [8,13] found a shorter EMD in a stretched muscle, [2] by contrast found a shorter EMD in an unstretched muscle.
Because existing results are not very satisfactory, it was the aim of the present study to more exactly elucidate the relation between IML and EMD.

METHODS: For purposes of this study, 18 male subjects performed four explosive maximal isometric voluntary contractions with their HS in six different length positions (Fig. 1), from unstretched (pos. 1) to stretched (pos. 6). The EMG-time-curves of m.biceps femoris (BF) and m.semitendinosus (ST) and the relevant force-time-curves were transduced by a Glonner-EMG-apparatus and digitally recorded with a sampling rate of 2 kHz. The bandpass-filtered (50-130Hz, Glonner) and rectified EMG and the force-time-curves were digitally lowpass-filtered (FIR) with a cut-off frequency of 30Hz. EMD was estimated by means of a specially designed computer program, which calculated the delay between the onset of the EMG and the onset of the mechanical force. The applied threshold level for both EMG and force was set at 1% of the maximum value in each position. Supplementarily the true-EMD (TEMD) [3] was defined as the EMD of the earlier onset of EMG of either BF or ST in each trial.

RESULTS: The results (Tab. 1) showed a dependence of EMD on IML. While pos. 3 and pos. 4 (OML) showed the shortest EMD (38-42ms), an increment of

EMD was to be seen in the direction of both stretched (46-49ms) and unstretched (42-45ms) IML. TEMD, as well as EMD of BF and ST, showed the same course of EMD-length-curve (Fig. 2). The results in OML were distinctly greater than in recent studies [4,6] for the same muscle group, but consistent with the lowest values reported for the hip flexors (32ms) [9]. Attributable to the small differences between the EMDs of the other positions, there were only significant differences between pos. 3 and pos. 6 in all EMDs and between pos. 5 and pos. 6 in TEMD.

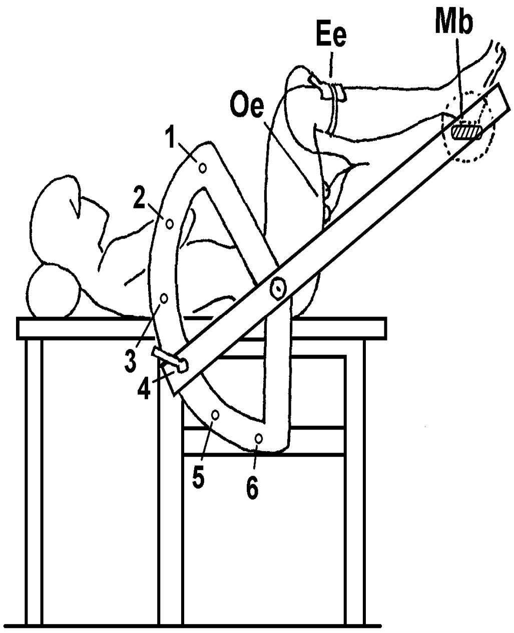

Figure 1: Experimental station to pick up the EMG- and force-time-curves of the hamstrings for determination of EMD: Oe - surface electrodes to pick up the voluntary activity of the hamstrings; Ee - ground electrode; Mb - strain gauge to pick up the explosive force; 1..6 - initial muscle length position

Table 1: Force- and EMD-values, significant differences between EMD-positions

	F [%]		BF		ST		TEMD	
	[% max]	Stdev	[ms]	Stdev	[ms]	Stdev	[ms]	Stdev
Pos. 1	50,0	8,2	44,0	10,3	42,2	12,5	45,1	11,2
Pos. 2	66,3	10,4	41,9	9,2	39,6	9,5	43,3	8,7
Pos. 3	79,9	10,9	38,9	6,2	38,1	6,5	40,9	6,1
Pos. 4	86,7	9,1	41,8	9,1	41,2	10,0	41,3	13,6
Pos. 5	83,6	13,3	41,9	6,7	41,0	7,2	42,7	7,0
Pos. 6	74,1	14,5	46,0	8,9	45,8	9,1	48,5	9,1
p<=.01	Pos.		3-6		3-6		3-6	
p<=.05	Pos.						5-6	
p<=.10	Pos.		1-3		2-6, 5-6		2-6, 4-6	

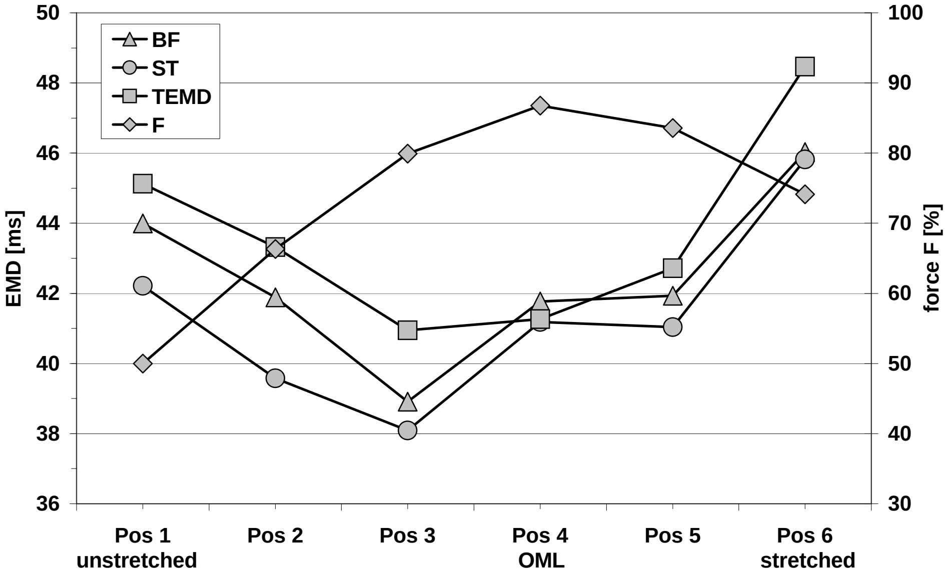

Figure 2: EMD and force in different IML-positions.

CONCLUSIONS: Maximum differences of about 8ms or 20% of EMD in different IML are not negligible in exact motion analysis. Therefore IML must be considered in order that knowledge of EMD can provide exact conclusions concerning the mechanical effectiveness of a particular muscle.

Surprisingly, and in contrast to previous results, the EMD-length-curve shows neither a positive nor a negative relation to the IML. EMD-length-curves in course rather seem to correspond with the inverse force-length-curve. This discrepancy may be due to the fact that in earlier publications at the most only two positions of IML were compared. Thus a line as a hypothetical direct connection between an unstretched (pos. 1, Fig. 2) and a stretched position (pos. 6) shows a negative relation between EMD and IML, whereas a line between an unstretched (pos. 1) and a stretched position (pos. 5) shows a positive relation.

It must be concluded that EMD is not directly dependent on IML, but rather on the maximum force and the rate of force development (RFD), which depends on the degree of overlapping of the sarcomeres in different length positions. The relation between maximum force respecting RFD and EMD will be confirmed by the fact that the onset of force was defined as the moment when force exceeds a threshold level of 1% related to the maximum force in each position. Therefore the conclusion was ruled out that in different IML different time intervals also exist to reach an IML-independent force level because of different maximum forces.

However, it may be the case that the relation between maximum force and EMD is caused by the time for the contractile elements (CE) to develop a continuous tension at the series elastic elements (SE). Dependent on the degree of overlapping, single sarcomeres produce lower forces by time in both directions from OML. This should result in different time intervals to reach the same continuous tension in the sarcomer-chain between both ends of the fiber.

Furthermore, in all publications on this subject the major portion of EMD, with references to Cavanagh & Komi [1,7], is referred to as the time it takes to stretch the SE by the CE. But in contrast to this present definition, proceeding from pos. 3 (Fig. 2) both EMD and muscle tension increase continuously in more stretched IML.
These results and the enormous differences in existing EMD values underline the importance of further investigation of EMD and suggest that we redefine EMD in different IML for all muscles involved in athletic motions.

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