# IS ELECTROMECHANICAL DELAY MISINTERPRETED?

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**KEY WORDS:** electromechanical delay (EMD), hamstrings (HS), muscle length, explosive force, series elastic elements (SE), contractile elements (CE)

**INTRODUCTION:** In the contraction of skeletal muscles a distinct phase-shift occurs between the electrical activity (EMG onset) and the mechanical response (force onset). This time shift is called motor time [12] or electromechanical delay (EMD, [1,7]. The exact value of EMD remains a factor of uncertainty. Recent results show an EMD of 24ms [4,6] for the HS in an optimal muscle length (OML). Therefore these values are distinctly shorter than any ever determined for voluntary contractions of the hip flexor muscles ranging between at least 32ms [11] and 118ms [5]. According to the related publications, EMD contains several components, which are linked to the force generation: the conduction of action potential along the T-tubuli system, the release of $Ca^{2+}$ by the sarcoplasmatic reticulum, the cross-bridge formation between actin and myosin, the tension development in the contractile element (CE) and the time it takes to stretch the series elastic elements (SE) by the CE [1,7]. In all publications on this subject the major portion of EMD, with direct or indirect references to [1,7], is referred to the last component, the stretching of the SE. Therefore it is concluded that all factors shortening (lengthening) the time for the stretching of the SE also shorten (lengthen) the EMD [10]. This seems to be confirmed by investigations showing shorter EMD in stretched muscle (SM) than in unstretched muscle (UM) [8,9,14], whereby there are also contrary examples [2,3]. However, it is not considered that in physiological positions a permanent tension exists in SE comparable with a stretched rubber band, and they do not slacken. Therefore a force generated by the CE at one end of the SE can only have a stretching effect if the other end of the SE is held back by the same amount of counter-force. It is of decisive importance that this happens at the same time without any delay. Thus it was the purpose of the present study to show experimentally that EMD cannot be determined by the time for stretching the SE.

**METHODS:** 18 male subjects participated in the study. They 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 concerning force-time-curves were transduced by a Glonner-EMG-equipment 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 to 1% of the maximum value (1%max). Furthermore a second threshold level for the force was set to 1% of the maximum value related to each position (1%mp). Supplementary the true-EMD (TEMD) [3] was defined as the EMD of the earlier onset of EMG of either BF or ST.

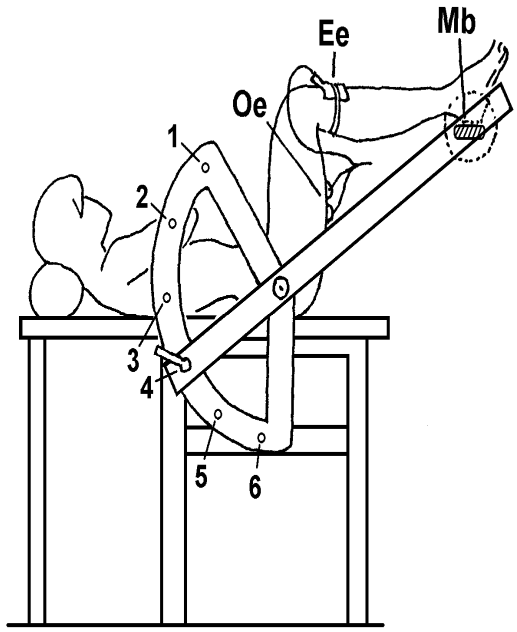



**Figure 1**: Experimental station to pick up the EMG- and force-time-curves of the hamstrings for determination of EMD: Oe - surface electrodes to pick up the voluntary activity of the hamstrings; Ee - ground electrode; Mb - strain gauge to pick up the explosive force; 1..6 - initial muscle length position

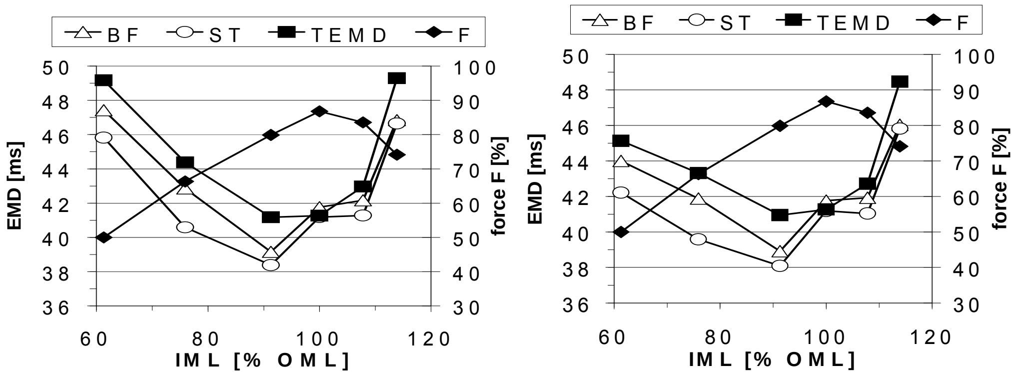
**RESULTS:** The results (Tab. 1, fig. 2) showed the shortest EMD (38-41ms) in pos. 3 and pos. 4 (OML, TEMD), while an increment of EMD was to be seen in the direction of both stretched (46-49ms) and unstretched (42-49ms) IML. The results in OML were distinctly greater than in recent studies [4,6] for the same muscle group but in good accordance with the shortest values reported for the hip flexors [9]. TEMD as well as EMD of BF and ST showed a similar course of EMD-length-curve. Attributable to the small differences between the EMDs of the other positions there were only significant differences between pos. 1 and pos. 3 (only 1%max), pos. 3 and pos. 6 and between pos. 5 and pos. 6 (only TEMD).

**CONCLUSIONS:** Surprisingly, and in contrast to former results, EMD-length-curve shows neither a positive nor a negative relation to the IML. This discrepancy may be due to the fact that in former 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. 2a) and a stretched position (pos. 5) shows a negative relation between EMD and IML, whereas a line between an unstretched (pos. 2) and a stretched position (pos. 6) shows a positive relation.
To exclude effects that in different IML, because of different maximum forces, also different time intervals exist to reach an IML-independent force level, a

supplementary onset of force was defined as the moment when the force exceeds a threshold level of 1% related to the maximum force in each position. Particularly in this case EMD-length-curves in course rather seem to correspond with the inverse force-length-curve (fig. 2b), but the fundamental EMD-length-curve course is not changed. This phenomena could be attributed to the maximum force and the rate of force development, which depends on the degree of overlapping of the sarcomeres in different IML.

**Table 1**: Force and EMD in different IML; IML from pos.-no. converted into %-OML [13], force F and EMD-values of BF, ST and TEMD, related to a force threshold of 1%max and 1%mp, significant differences between EMD-positions.

| IML | | F | BF | | ST | | TEMD | |
|---|---|---|---|---|---|---|---|---|
| | | | 1%max | 1%mp | 1%max | 1%mp | 1%max | 1%mp |
| Pos.-no. | [% OML] | [% max] | [ms] | [ms] | [ms] | [ms] | [ms] | [ms] |
| Pos. 1 | 61,3 | 50,0 | 47,4 | 44,0 | 45,8 | 42,2 | 49,2 | 45,1 |
| Pos. 2 | 75,9 | 66,3 | 42,9 | 41,9 | 40,6 | 39,6 | 44,4 | 43,3 |
| Pos. 3 | 91,3 | 79,9 | 39,2 | 38,9 | 38,4 | 38,1 | 41,2 | 40,9 |
| Pos. 4 | 100,0 | 86,7 | 41,8 | 41,8 | 41,2 | 41,2 | 41,3 | 41,3 |
| Pos. 5 | 107,8 | 83,6 | 42,2 | 41,9 | 41,3 | 41,0 | 43,0 | 42,7 |
| Pos. 6 | 113,9 | 74,1 | 46,8 | 46,0 | 46,6 | 45,8 | 49,3 | 48,5 |
| p<=.01 | | Pos. | 3-6 | 3-6 | 3-6 | 3-6 | 3-6 | 3-6 |
| p<=.05 | | Pos. | 1-3 | | 1-3 | | 1-3, 5-6 | 5-6 |
| p<=.10 (trend) | | Pos. | | 1-3 | 2-6, 5-6 | 2-6, 5-6 | 1-4, 1-5, 2-6, 4-6 | 2-6, 4-6 |




**a) EMD related to 1%max** **b) EMD related to 1%mp**

**Figure 2**: EMD- and force-length-curves.

Furthermore, the results show distinctly that proceeding from pos. 3 (tab. 1, Fig. 2) both EMD and muscle tension increase continuously in more stretched IML. Therefore it must be concluded that in contrast to previous results [1,7] EMD cannot be determined by the time it takes to stretch the SE by the CE. Rather it

may be speculated that the relation between maximum force and EMD is caused by the time for the CE to develop tension at the SE. Dependent on the degree of overlapping, single sarcomeres produce lower forces by time in both directions from OML. That should lead to longer time intervals to reach a continuous and measurable tension in the sarcomer-chain between both ends of the fiber.
However, these results impressively underline the importance of further investigation of EMD and suggest that we have to redefine EMD.

**REFERENCES:**


1. Cavanagh, P. R., Komi, P. V. (1979). Electromechanical Delay in Human Skeletal Muscle under Concentric and Eccentric Contractions. *Europ. J. of Appl. Phys.* **42**, 159-163.
2. Corser, T. (1974). Temporal Discrepancies in the Electromyographic Study of Rapid Movement. *Ergonomics* **17**, 389-400.
3. Grabiner, M. D., Jaque, V. (1987). Activation Patterns of the Triceps Brachii Muscle during Sub-Maximal Elbow Extension. *Med. & Sci. in Sports & Exerc.* **19**(6), 616-620.
4. Hahn, K.(1992). Der Einfluß eines kurzzeitigen Krafttrainings auf verschiedene Funktionsparameter der ischiocruralen Muskulatur. Unpublished Examination Paper. Wuppertal: Bergische Universität-Gesamthochschule.
5. Horita, T., Ishiko, T. (1987). Relationships between Muscle Lactate Accumulation and Surface EMG Activities during Isokinetic Contractions in Man. *Europ. J. of Appl. Phys*. **56**, 18-23.
6. Jöllenbeck, T. (1997). Electromechanical Delay of the Hamstrings and its Significance for the Analysis and Optimisation of Sprint Running. *Congress: Sport Kinetics '97. Magdeburg:* in press.
7. Komi, P. V., Cavanagh, P. R.(1977). Electromechanical Delay in Human Skeletal Muscle. *Med. & Sport Sci.* **10**, 49.
8. Laine Santa Maria, D.(1970). Premotor and Motor Reaction Time Differences Associated with Stretching of Hamstring Muscle. *J. of Mot. Behav.* **2**, 163-173.
9. Muro, M., Nagata, A. (1985). The Effects on Electromechanical Delay of Muscle Stretch of Human Triceps Surae. In D. A. Winter, R. W. Norman, R. P. Wells, K. C. Hayes, A. E. Patla (Eds.), *Biomechanics IX-A* (pp. 88-90). Champaign, Ill.: Human Kinetic Publishers.
10. Norman, R. W., Komi, P. V. (1979). Electromechanical Delay in Skeletal Muscle under Normal Movement Conditions. *Acta Physiol. Scand*. **106**, 241-248.
11. Symons, J. D., Bell, D. G., Pope, J., van Helder, T., Myles, W. S. (1988). Electromechanical Response Times and Muscle Strength after Sleep Deprivation. *Can. J. of Sport Sci.* **13**, 225-230.
12. Weiss, A. D. (1965). The Locus of Reaction Time Change with Sex, Maturation and Age. *J. of Gerontol.* **20**, 60-64.
13. Wiemann, K. (1991). Beeinflussung muskulärer Parameter durch ein zehnwöchiges Dehnungstraining. *Sportwissenschaft* **21**(3), 295-306.
14. Zhou, S., Lawson, D. L., Morrison, W. E., Fairweather, I. (1995). Electromechanical Delay in Isometric Muscle Contractions Evoked by Voluntary, Reflex and Electrical Stimulation. *Europ. J. of Appl. Phys*. **70**(2), 138-146.