MUSCULAR ACTIVITY IN THE STRETCH-SHORTENING CYCLE (SSC): NOT ONLY MAXIMIZATION BUT OPTIMIZATION IS NECESSARY

Anke Neubert, Ansgar Schwirtz, Martin Bührle,
Albert-Ludwigs-Universität, Freiburg, Germany

INTRODUCTION: Drop jumping is a very complex skill with a stretch-shortening cycle (SSC) involving several phases – preparation for landing, landing itself, shock absorption and push-off. Only a very short span of time (≤ 200ms) is available for the execution of a drop jump. For this reason much is required of the jumper's neuromuscular system. Especially an EMG reduction of m. gastrocnemius activity just before and at the beginning of landing has been reported several times (Schmidtbleicher/Gollhofer, 1985). This reduction has been interpreted as a mechanism to protect the muscle from excessive stretch loads. Previously, only qualitative results have been reported.

METHODS: Reactive capabilities were analyzed in two complex studies of 18 sport students. The following movements were studied: squat jumps, counter- movement jumps and drop jumps from drop heights of 16, 24, 32, 40, 48 and 56 cm. EMG-activities of the m. tibialis anterior, m. soleus, m. gastrocnemius and m. rectus femoris were registered to describe muscle activity during vertical jumping. Simultaneously, ground reaction forces and changes in knee angle were registered. Five jumps in each experimental condition were averaged for each subject using the early touchdown of the feet on the platform system for synchronization (see Fig. 1)

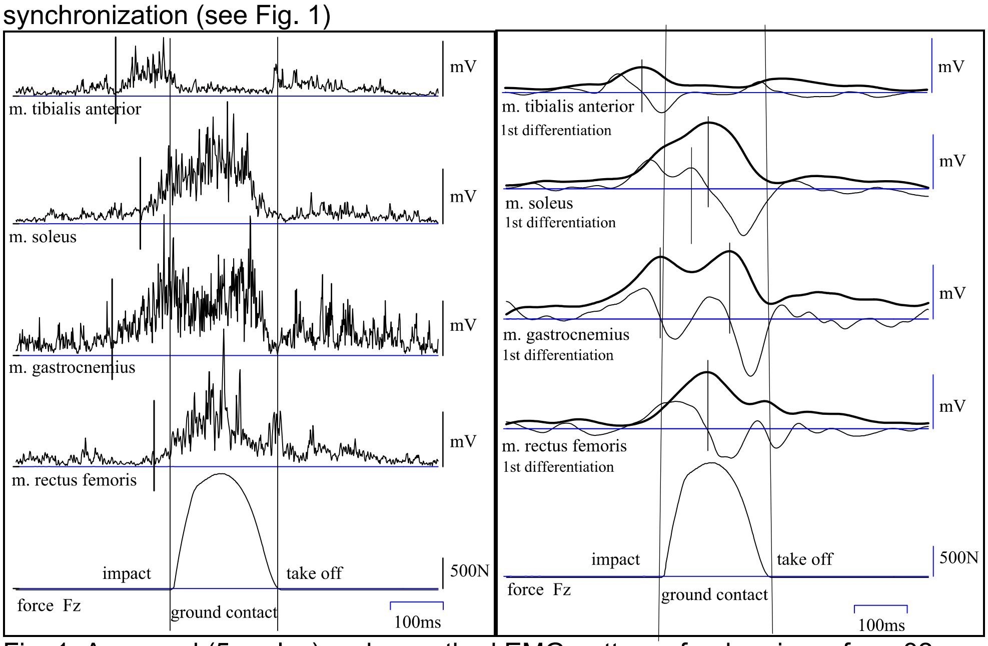


Fig. 1: Averaged (5 cycles) and smoothed EMG-pattern of a drop jump from 32 cm

A new method was developed for measuring the EMG-reduction of m. gastrocnemius. In this analysis, the EMGs were smoothed with a 10 Hz low pass filter. For quantitatively determining the maxima and minima of the muscle activity, these smoothed EMGs were differentiated (Fig. 2). The following parameters were calculated: for a temporal characterization of EMG-reduction: duration of activity reduction of m. gastrocnemius (1), the time of the minimal amount of activity after impact (5) and the lapse of time between the beginning of reduction and the impact (6). To characterize the height of innervation in the defined moments: the amount of activity at the beginning of reduction (2), the minimal amount of activity (3), the amount of activity at the end of reduction (4). By the same means, the amount and the temporal localization of maximal activity were analyzed for all muscles.

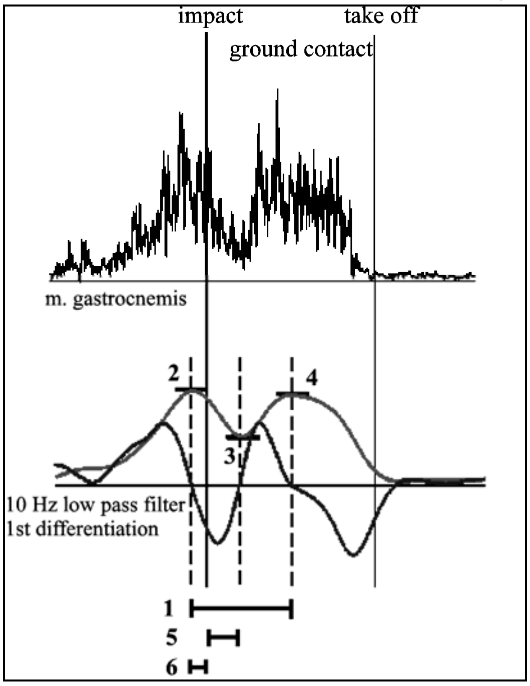


Fig. 2: Parameters for characterization of EMG reduction of m. gastrocnemius (explanations see text)

RESULTS: To demonstrate the results, the parameters of the drop jump from a drop height of 40 cm were chosen. The subjects reached a mean jump height of 26.4 cm, the time of ground contact was 196 ms (see table 1). This means that all participants in this study were able to realize reactive drop jumps, they reached contact times shorter than 200 ms and represent a homogeneous group in regard to contact time.

With regard to EMG patterns, the results showed, firstly, that almost all subjects (16 of 18 subjects, also the good jumpers) realize different drop jumps showing an activation pattern with a reduction of m. gastrocnemius. This EMG-reduction starts about 20 ms before impact (6) and lasts for more than 50% of ground contact (1). On an average, the amount of maximal activity during ground contact is a little higher than at the beginning of reduction (2,4).

Secondly, it could be observed that EMG-reduction of m. gastrocnemius begins simultaneously with the preactivation of m. rectus femoris. During ground contact, m. gastrocnemius reaches minimal activity while m. rectus femoris reaches maximal innervation (5, RFmax). There is no statistically significant difference between either the moments of maximal innervation of m. gastrocnemius (6) and m. rectus femoris preactivation or the moments of minimal innervation of m. gastrocnemius and maximal innervation of m. rectus femoris during ground contact.

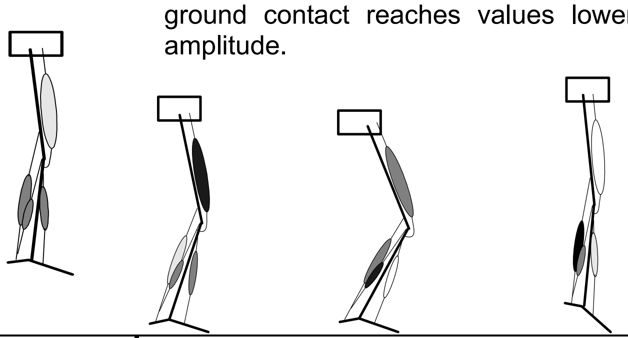
	Duration of EMG reduction [ms] par 1	relative to time ground contact [%]	GA max 1 [ms] par 6	RF preactivation [ms]	GA min [ms] par 5	RF max [ms]	GA max 2 [ms] par 1-6
mean	**131**	**64**	**-24**	**-34**	**55**	**62**	**107**
s	30	15	18	17	15	17	35
	A max 1 [%] par 2	A min [%] par 3	A max 2 [%] par 4			Jump-height [cm]	Ground contact [ms]
mean	**132**	**99**	**148**			**26,4**	**196**
s	19	17	14			5,0	17

Tab. 1: Mean and standard deviation of different parameters to describe the intermuscular coordination of m. gastrocnemius and m. rectus femoris in dropjumping, drop height 40 cm. (n=16, numbers of parameter correspond to Fig. 2, negative values are located before impact, for parameter 2,3, and 4 the mean amplitude of m. gastrocnemius corresponds to 100%)

INTERPRETATION: During the phase of preactivity, the m. gastrocnemius is the first muscle to show activity. Its function is to stabilize the knee joint in an optimal landing position (slightly bent). The function of the antagonistic m. rectus femoris innervation during preactivity is to stop further bending and stabilize the knee joint. The m. gastrocnemius activity must be reduced to not disturb this mechanism.
During ground contact, strong action in the knee joint is demonstrated by the activity of the leg extensor m. rectus femoris, which is needed to stop downward movement and start the push-off (see Fig. 3). The m. gastrocnemius' activity with its antagonistic effect on the knee joint was reduced when m. rectus femoris activity started, and reached maximal innervation significantly later than m. rectus femoris. There is only a functional-anatomical interpretation of this mechanism. The m. gastrocnemius shows only a little activity until the m. rectus femoris has fulfilled its function of knee extension. Afterwards, high m. gastrocnemius activity is needed to slow down the velocity of knee extension and to make possible an impulse transfer from the knee joint to the ankle joint. In this situation, the m. gastrocnemius works under virtually isometric conditions, so that it reaches an optimal force-velocity-relation.
This is especially the case for good jumpers. After a training period of four weeks (only reactive movements) this program of innervation could be observed in almost all the participants in these studies.

CONCLUSION: The results show that for these subjects and for the tested drop heights the EMG reduction of m. gastrocnemius during drop jumping cannot be considered a reliable mechanism to protect the muscle from excessively large stretch loads, but that this EMG activity of the antagonistic muscles makes possible an optimal intermuscular coordination for drop jumping.

When the drop height increases, a transition from an optimal intermuscular coordination for drop jumping to a protective mechanism takes place. This is seen in the EMG pattern, when the minimal innervation of m. gastrocnemius during ground contact reaches values lower than 50% of mean amplitude.



knee angle: 170°		150°	130°	175°	
	flight phase up to 200 ms pre-act.	ground contact (ca. 200 ms) ca. 50 ms landing	ca. 50 ms Shock-absorbtion	ca. 100 ms push-off (hip-extension, knee-extension, foot-extension)	take off
TA	Stabilization of the ankle joint				
SO	Stabilization of the ankle joint		prevents from heel contacting		
GA	Stabilization of the knee joint			slows down the knee extension, impulse transfer	
RF		avoids knee bending			

Fig. 3: Schematic representation of activation patterns and of intermuscular coordination of TA, SO, GA and RF and their function in the DJ.

= no activity	= average activity
= little activity	= maximal activity

The transfer of these results and this functional-anatomical interpretation to training methodology means that stretch-shortening typed training is rather coordination than strength training.

Van Soest, A., Schwab, A., Bobbert, M., Van Ingen Schenau, G. (1993). The Influence of the Biarticularity of the Gastrocnemius Muscle on Vertical Jumping Achievement. *J. of Biomech.* **26**(1), 1-8.

Bührle, M. (1989). Maximalkraft - Schnellkraft - Reaktivkraft. Kraftkomponenten und ihre dimensionale Struktur. *Sportwissenschaft* **3**, 311-325.

Gollhofer, A. (1993). Belastungsvariation und motorische Koordination. Habilitationsschrift. Freiburg.

Rapp, W., Gollhofer, A. (1996). Einfluß visueller Information auf die Bewegungsprogrammierung bei reaktiven Bewegungsabläufen. In A. Gollhofer, *Integrative Forschungsansätze in der Bio & Mechanik* (pp. 81-88). Sankt Augustin: Academia.

Schmidtbleicher, D., Gollhofer, A. (1985). Einflußgrößen des reaktiven Bewegungsverhaltens und deren Bedeutung für die Sportpraxis. In M. Bührle, *Grundlagen des Maximal- und Schnellkrafttrainings* (pp. 271-281). Schorndorf: Hofmann.