EVALUATION OF PASSIVELY INDUCED SHOULDER STRETCH REFLEX USING AN ISOKINETIC DYNAMOMETER IN MEN

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The purpose of the current study was to determine shoulder internal rotator muscles' reflex latencies (SLR) under variable conditions in 20 healthy, specifically trained male participants. Sets of different external shoulder rotation stretches were applied via an isokinetic dynamometer. SLR latencies were determined from sEMG readings as the time from external shoulder rotation stretches application to onset of muscle activity. The amount of muscular response to the perturbation was evaluated via a peak-to-peak analysis. SLR latencies and amplitudes of the pectoral muscle and the anterior deltoid were affected by the investigated muscle and the level of pre-innervation torque. Our results indicated faster muscular stretch response than reported in previous studies which can be attributed to training induced adaptions of the shoulder muscles and capsule.

KEY WORDS: elastic energy storage, shoulder perturbation, external shoulder rotation, monosynaptic stretch reflex

INTRODUCTION: The glenohumeral joint possesses a multiple number of degrees of freedom, which yield a high level of mobility necessary for specific tasks. Due to its joint architecture inherent shoulder joint stability is compromised. To ensure stability the shoulder relies on different static and dynamic restraints. Static restraints include osseous geometry, negative intraarticular pressure, the glenoid labrum, and capsuloligamentous restraint (O'Brien, Warren, & Schwartz, 1987). Dynamic restraints refer to shoulder stability through mechanical and neuromuscular mechanisms by muscles that cross the shoulder. A working neurological interaction between these two mechanisms (static and dynamic restraint) ensures joint stability (Myers & Lephart, 2000). Reflexive muscle contractions are reported to protect joints via a subsequent increase in muscle stiffness (Shemmell, Krutky, & Perreault, 2010). Several investigations examined muscular reflexes in the lower limb (cf. Simonsen, 2014) whereas only limited knowledge about upper limb muscle reflexes exists. To our knowledge only few publications with comparable test settings investigated shoulder muscle reflex latencies (Brindle, Nyland, Shapiro, Caborn, & Stine, 1999; Latimer, Tibone, Pink, Mohr, & Perry, 1998; Myers et al., 2003; Wallace, Beard, Gill, Eng, & Carr, 1997). Observed latencies ranged from 110 to 220 ms whereupon the anterior muscles responded faster than the posterior muscles (Latimer et al., 1998) which therefore seem to be too slow to protect the shoulder due to reflex induced stiffness elevation. The purpose of this study was to examine whether specifically trained participants showed a different muscular response to a rapid anterior perturbation of the shoulder than those reported in the literature. We hypothesized that our participants reveal shorter reflex latencies due to their training induced adaptions of the shoulder muscles and capsule (Wieser, Gerber, & Meyer, 2016).

METHODS: Twenty healthy right handed men (age: 22.9±2.38y, height: 182.7± 5.8cm, weight: 83.1± 8.5kg) who had performed an overhand sport (javelin throw, volleyball, handball) for at least 4 years with a minimum of two training sessions per week (2 to 6 sessions/week) participated. The study consisted of one familiarization and one test session. Subjects were seated on an isokinetic dynamometer (IsoMed2000, D&R GmbH, Hemau, Germany) in an upright trunk position with their left shoulder supported by a special backpad. The dominant right arm was abducted at 90° and the elbow was flexed at 90°. The resulting position was defined as start setting (90/90-position) for the external shoulder rotation trials.

We determined maximum isometric torque (T_{MVC}) from at least 3 trials of maximum isometric contraction (MVC) of each subject in the 90/90-position with 2 minutes break between trials. The highest torque value during a steady plateau was used as T_{MVC}. The individual maximum external stretch amplitude (iMAX) for each participant was determined at the same stretch velocity that was used during the test session (150°/s). External shoulder rotation stretches were applied during the test session at a range of amplitudes and with different pre-activation torque levels relative to the torque values of the MVC-test (Table 1).

Table 1. Experimental conditions. The order of stretch conditions was randomized. (iMax: individual maximal stretch amplitude, T_{MVC}: maximum voluntary contraction)

Condition	Stretch amplitude (%of iMAX)	Stretch velocity (°/s)	Pre-innervation level (% of T_{MVC})
Warm-Up	-	15	-
Internal MVC	-	-	-
External Stretch	50	150	0
	50	150	25
	50	150	50
	100	150	0
	100	150	25
	100	150	50

All stretches were applied with a dynamometer acceleration of $10°/ms^2$. Surface EMG (sEMG) activity of the primary internal rotator muscles of the shoulder (pectoral muscle, anterior deltoid and latissimus dorsi muscle) was recorded at a sampling frequency of 2000Hz via an A/D board (National Instruments, Austin, USA) and Templo 7.1 Software (Contemplas GmbH, Kempten, Germany). For EMG data processing MATLAB R2015b software (MathWorks, Natick, USA) was used. The mechanical delay of the trials was measured by two accelerometers attached to the dynamometer and to the insertion of the pectoral muscle respectively. EMG signals were demeaned and bandpass zero-lag filtered (10-450Hz) with a digital fourth-order Butterworth filter for further analysis. The short latency stretch reflex (SLR) was manually identified. The peak-to-peak amplitude was calculated for the selected part of the signal. All statistical data analyses were carried out on SPSS 24 (IBM Corporation, Armonk, USA). Two three-way within subjects repeated measures ANOVA were performed. Bonferroni's post hoc analyses were used for pairwise comparisons. To analyse significant discrepancy between pre and post MVC-tests a paired *t* test was carried out.

RESULTS: Consistent SLRs were observed in only particular experimental conditions. For stretches performed with 50% MVC pre-innervation torque the SLR could not unequivocally be determined in any muscle. Furthermore the latissimus dorsi muscle showed consistent stretch response only under particular test conditions. Statistical analysis of the reflex latencies revealed a significant muscle main effect ($F(2,18) = 68.49$, $p < 0.001$) ($\eta^2 = .783$) and a significant pre-innervation main effect ($F(1,19) = 38.15$, $p < 0.001$) ($\eta^2 = .668$). Comparison among muscles at different levels of pre-innervation torque and applied stretch amplitude revealed the sternal pectoral muscle head reflex latency to be significantly slower than the clavicular pectoral muscle head and the anterior deltoid (Fig 1). Analysis of the stretch reflex amplitude revealed a significant pre-innervation main effect ($F(1,19) = 154.90$, $p < 0.001$) ($\eta^2 = .891$). In addition a muscle by pre-innervation interaction could be observed ($F(2,38) = 3.36$, $p = 0.045$). Comparisons among the tested muscles at different levels of pre-innervation torque and applied stretch amplitude presented a significantly stronger muscle response in all muscles to the external rotation stretches in case of muscle pre-innervation (Fig 2). No differences were observed in MVC torque when comparing the beginning and end of the protocol (pre:88.68±15.06Nm, post:88.56±14.83Nm).

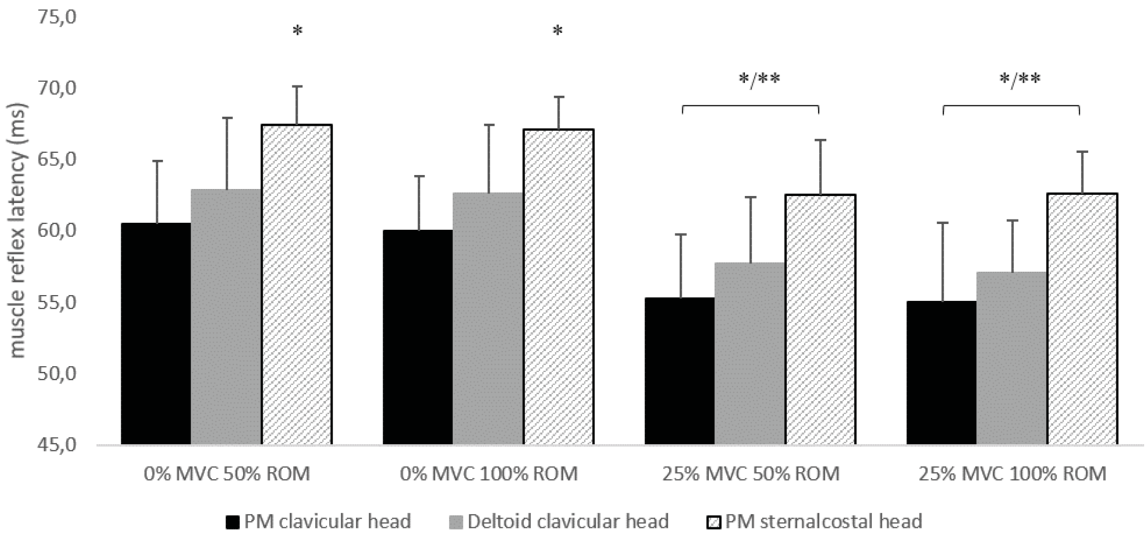

Fig 1. Shoulder muscle reflex latencies in all tested conditions and muscles. *Pectoralis major (PM) sternal head reflex latencies were significantly slower than the PM clavicular head and the Deltoid clavicular head in all tested conditions. **Muscle pre-innervation caused significantly faster reflex latencies in all tested muscles.

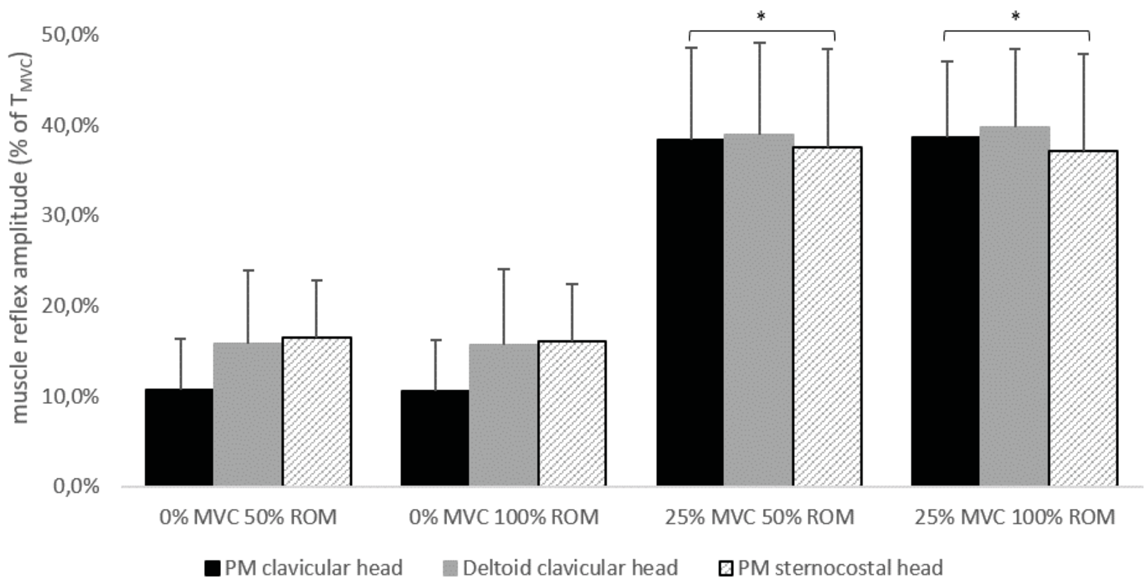

Fig 2 Shoulder muscle reflex amplitude in all tested conditions and muscles. *Pre-innervation caused significant higher reflex amplitude in all tested muscles.

DISCUSSION: The beneficial influence of muscle pre-innervation on reflex latency and amplitude can be explained by an increase in muscle spindle sensitivity to intramuscular lengthening (Myers & Lephart, 2000). The latissimus muscle is particularly activated during the late cocking phase and the early acceleration phase during overhand throwing which explains the lack of latissimus muscle stretch response. In contrast to previous research, in our study a muscle pre-innervation level of 50% MVC torque yielded no consistent stretch reflex in any of the investigated muscles (Myers et al., 2003). We attributed the lack of consistent reflexive muscle responses to the considerably high background activation achieved during the pre-innervation phase. Since electromyography measures the degree of muscle activation and the electrophysiological activation of a muscle initiates force generation strong evidence indicates that higher EMG levels correlate with higher muscle force (Disselhorst-Klug, Schmitz-Rode, & Rau, 2009). Furthermore Cronin et al. (2008) revealed a negative correlation between higher forces and short-latency stretch reflex behavior. They showed a decline in fascicle stretch velocity of over 50% between passive conditions and maximal force levels resulting in progressively smaller muscular stretch response. The results of our study indicate up to three times faster muscular stretch response than formerly observed in the literature (cf. Latimer et al., 1998; Myers et al., 2003). We assumed that training induced adaptions of the shoulder muscles and capsule are responsible and therefore trained subjects are rather capable of an utilization of stretch induced muscle activation patterns which could lead to stiffness regulation and elastic energy storage at the shoulder.

CONCLUSION: The results of the current study indicate significantly faster reflex latencies than those reported so far. Although the reflex latencies quicken when the muscle is pre-innervated the question still remains how these observations fit into high velocity movement execution. Furthermore, the role these reflexes play in maintaining joint stability needs to be clarified by further investigations.

REFERENCES:

Brindle, T. J., Nyland, J., Shapiro, R., Caborn, D. N., & Stine, R. (1999). Shoulder proprioception: latent muscle reaction times. *Med Sci Sports Exerc, 31*(10), 1394-1398.

Cronin, N. J., Peltonen, J., Ishikawa, M., Komi, P. V., Avela, J., Sinkjaer, T., & Voigt, M. (2008). Effects of contraction intensity on muscle fascicle and stretch reflex behavior in the human triceps surae. *J Appl Physiol (1985), 105*(1), 226-232. doi:10.1152/japplphysiol.90432.2008

Disselhorst-Klug, C., Schmitz-Rode, T., & Rau, G. (2009). Surface electromyography and muscle force: limits in sEMG-force relationship and new approaches for applications. *Clin Biomech (Bristol, Avon), 24*(3), 225-235. doi:10.1016/j.clinbiomech.2008.08.003

Latimer, H. A., Tibone, J. E., Pink, M. M., Mohr, K. J., & Perry, J. (1998). Shoulder reaction time and muscle-firing patterns in response to an anterior translation force. *J Shoulder Elbow Surg, 7*(6), 610-615.

Myers, J. B., & Lephart, S. M. (2000). The role of the sensorimotor system in the athletic shoulder. *J Athl Train, 35*(3), 351-363.

Myers, J. B., Riemann, B. L., Ju, Y.-Y., Hwang, J.-H., McMahon, P. J., & Lephart, S. M. (2003). Shoulder Muscle Reflex Latencies Under Various Levels of Muscle Contraction. *Clinical Orthopaedics and Related Research, 407*, 92-101. doi:10.1097/00003086-200302000-00017

O'Brien, S. J., Warren, R. F., & Schwartz, E. (1987). Anterior shoulder instability. *Orthop Clin North Am, 18*(3), 395-408.

Shemmell, J., Krutky, M. A., & Perreault, E. J. (2010). Stretch sensitive reflexes as an adaptive mechanism for maintaining limb stability. *Clin Neurophysiol, 121*(10), 1680-1689. doi:10.1016/j.clinph.2010.02.166

Simonsen, E. B. (2014). Contributions to the understanding of gait control. *Dan Med J, 61*(4), B4823.

Wallace, D. A., Beard, D. J., Gill, R. H., Eng, B., & Carr, A. J. (1997). Reflex muscle contraction in anterior shoulder instability. *J Shoulder Elbow Surg, 6*(2), 150-155.

Wieser, K., Gerber, C., & Meyer, D. C. (2016). The Throwing Shoulder. *Praxis (Bern 1994), 105*(3), 159-165. doi:10.1024/1661-8157/a002252