# Abstract Template for ISB2025 in Stockholm

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## Summary

This study investigated the effects of a gradual increase in voluntary activation to varying target levels during the stretch phase on force and work production during the subsequent shortening phase of the stretch-shortening cycle (SSC) in *in-vivo* human knee extensors. Force and work enhancement during the shortening phase of the SSC following all active stretch conditions was observed. The increase in force and work during the early shortening phase was primarily attributed to pre-activation. In contrast, fascicle behavior and intrasarcomeric structural dynamics likely contributed to the continued enhancement observed during the later shortening phase. Furthermore, as the activation level during the stretch phase of the SSC increased, the subsequent steady-state isometric force was more significantly depressed. These findings underscore the importance of the integrated mechanisms of SSC effect in natural human movements.

## Introduction

The SSC enhances force and work output during dynamic movements predominantly driven by pre-activation and muscle-tendon elasticity. Two additional key contributors are the residual force enhancement (rFE) [1] and MTU decoupling [2]. Many studies have explored the SSC effect in natural human movements, while most experimental research has been conducted in highly standardized setups using maximum voluntary contractions or controlled electrical muscle activation [3]. However, muscle activation increases gradually during MTU stretching in human movements and reaches maximal levels during MTU shortening. Accordingly, this study investigates *in vivo* SSC behavior under gradual increases of muscle activation to varying target levels during the stretch phase and how this influences SSC performance and fascicle behavior during the shortening phase in the knee extensors.

## Methods

Fifteen young adults (10 males, 5 females) performed under four conditions, varying activation levels during the stretch phase: 0% ($ST_{0\%}$-SC), 40% ($ST_{40\%}$-SC), 80% ($ST_{80\%}$-SC), and 100% ($ST_{100\%}$-SC). In $ST_{0\%}$-SC, the stretch was passive, followed by maximal activation at the shortening onset. In $ST_{40\%}$-SC and $ST_{80\%}$-SC, activation increased gradually during the stretch phase to target levels, guided by real-time feedback. $ST_{100\%}$-SC involved maximal activation throughout. All shortening and isometric phases were performed with maximal voluntary activation. Repeated-measures ANOVA and SPM1d compared values across conditions.

## Results and Discussion

Higher activation during the stretch phase enhanced torque and work more during shortening (58% improvement) than $ST_{40\%}$-SC (17%). In $ST_{0\%}$-SC, the peak fascicle shortening velocity during the shortening phase was twice as fast as in other trials. The remaining force enhancement observed in $ST_{80\%}$-SC (Figure 1) suggests additional structural dynamics beyond activation [1]. Higher activation levels also increased force depression during subsequent isometric contractions (-12% for $ST_{100\%}$-SC, -7% for $ST_{80\%}$-SC, and -3% for $ST_{0\%}$-SC).

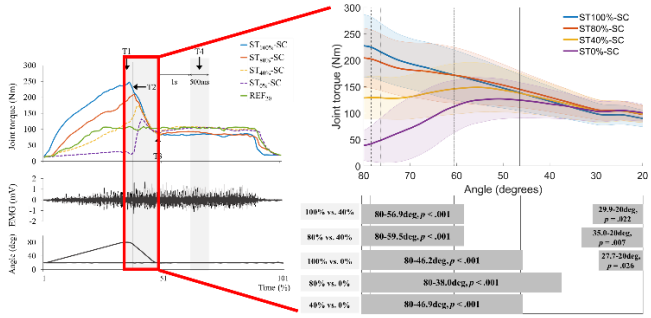


**Figure 1**: (a) exemplar torque-, EMG, and angle-time data. (b) Top: mean +/- SD of knee joint torque during the shortening phase (red box in a)—bottom: related zones of significant differences between conditions using SPM1d and Bonferroni-Holm post hoc correction.

## Conclusions

Increasing the pre-activation target level during the stretch phase enhances SSC force and mechanical work. Gradual activation up to 80% sustains benefits beyond the early shortening phase, suggesting an optimal level for maximizing SSC effects. The modulation of fascicle behavior by activation strategies highlights the integrated mechanisms of the SSC effect in natural movements.

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## References

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