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INFLUENCE OF INDUCED PLANTAR HYPOTHERMIA ON THE ACHILLES TENDON STRETCH REFLEX

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SUMMARY

Previous studies indicate that plantar cutaneous afferents participate in modulation of muscle reflexes; however, the mechanisms remain unclear. Thus, the aim of this study was to investigate the influence of hypothermically reduced plantar foot sensation on the Achilles tendon reflex. Short latency responses of three muscles were analyzed under three temperatures: Stage I (25°C), Stage II (12°C), Stage IIIa (0°C) and Stage IIIb (0°C). Hypothermia was induced by a self-built thermal-plate and controlled by an infrared thermal camera. Results showed significant delays only for M. soleus when comparing the first temperature conditions (25°C and 12°C) to the last one (0°C). However, these delays were not relevant. Further investigations are suggested to elucidate the role of afferent inputs of the foot sole on stretch reflex responses.

INTRODUCTION

The somatosensory, visual and vestibular inputs are integrated efficiently in order to control and coordinate different motor tasks. Particularly regarding the information of the somatosensory system, mechanoreceptors of the foot sole play an important role especially for balance and gait [1,2,3,4]. However, the mechanisms underlying the interaction of these different systems remain mostly unclear. Hence, current studies have tried to isolate the inputs of cutaneous receptors in healthy subjects to observe their association with muscle reflexes. Cutaneous afferents of the foot sole can be isolated through the application of different procedures, such as electrical stimulation [2,5], anesthesia [6] and cooling [4,8]. The modulation of the muscle activity was investigated after electrical excitation of plantar cutaneous afferents and latency facilitation was found for stretch reflexes [2,3,5]. However, contrary results were found after an inhibition of cutaneous inputs performed by a topical anesthesia of skin receptors, which evoked H-reflex facilitation [6]. Therefore, additional studies are necessary to comprehend the role of plantar cutaneous afferents on modulating muscle activity. Thus, the aim of this study was to investigate effects of reduced plantar foot sensation by a controlled temperature reduction on the Achilles tendon reflex. Based on findings of facilitation of the soleus reflex by stimulating plantar afferents [3], it was hypothesized that cooling of the foot sole skin as inhibition of mechanoreceptor inputs would cause an inverse response. Therefore, delays of short latency responses were expected for the Achilles tendon stretch reflex.

METHODS

The present study was approved by the Ethics Committee of the Chemnitz University of Technology. All procedures were conducted according to the recommendations of the Declaration of Helsinki. Achilles tendon reflexes of 52 healthy and injury-free subjects (26 male, 26 female; age: 24.2±3.2 years, height: 173±7.4 cm, weight: 66.3±10.1 kg) were analyzed. Prior to the measurements, all participants were informed about the purpose of this study and were instructed to interrupt the measurements in case of discomfort. Reflexes were evoked with taps against the Achilles tendon using an apparatus with a rotating metal reflex hammer. Five measurements were performed at the right leg in three pre-determined temperatures: Stage I (25°C), Stage II (12°C), Stage IIIa and Stage IIIb (0°C), respectively. A self-built, foot-shaped, customized thermal-plate was used to cool down the foot sole in controlled temperatures. Acclimatization times (time with the foot on the thermal-plate) were three minutes for Stage I and five minutes for Stages II, IIIa and IIIb. Plantar foot temperatures at the heel were measured by an infrared thermal camera ThermaCAM P25 (FLIR Systems, Inc.) and the room temperature was also controlled. Muscle activities were measured using surface electromyography (EMG) (8-channel Bagnoli System, Delsys Inc, USA) at 1000Hz. EMG-data were collected from three muscles: M. gastrocnemius medialis (GM), M. gastrocnemius lateralis (GL) and M. soleus (SO). Placement of the sensors was performed according to SENIAM recommendations [9]. Short latency response (SLR) was calculated considering the time between the moment in which the hammer hit the tendon until the time of reflex peak. Data were processed in R (The R Foundation for Statistical Computing, Austria) and statistical analysis was conducted in PASW Statistics 18.0 (SPSS Inc., USA). EMG values were compared between the temperature conditions with ANOVA for repeated measurements followed by Bonferroni post-hoc tests (p=0.05).

RESULTS AND DISCUSSION

Average room temperature was 22.8±0.8°C throughout the measurements. Skin temperatures at stage I and II were 24.2±0.8°C and 11.5±0.9°C, respectively. These temperatures were similar to the pre-determined temperatures (thermal-plate temperatures) 25°C and 12°C. However, for the 0°C conditions, mean skin temperatures were 6.4±1.2°C and 6.5±1.5°C for IIIa and IIIb, respectively. These measured temperatures above 0°C could be explained by the temperature-regulating mechanism (vasodilatation), which is a body protection system against hypothermia [11]. Nevertheless, since a variation of 5-6°C of the initial foot sole temperature is able to significantly influence the functionality of cutaneous mechanoreceptors [8], it can be stated that the reduction of temperature led to a reduced skin sensitivity at all hypothermic stages. A differential of the present study was the use of a thermal-plate, with which only the foot sole skin was cooled, thus avoiding interferences surrounding ankle receptors and muscle spindles of GM, GL and SO. Furthermore, the use of the thermal-plate has allowed maintaining the reached temperature values during the measurements, which is also an advantage compared to other cooling-methods (ice or water). Changes in time of short latency responses are presented in Table 1. Significant delays were only found for SO when comparing the first conditions (stage I and II) to the last one (0°C) (p=0.034 and p=0.015). Our results are in accordance with [7], which also showed delays in short and long latency responses on wrist flexor reflexes as response of core cooling. However, they observed delays of 5ms for short and 10ms for long latency responses. Despite statistical results indicating significant delays in SO, it should be noted that differences between latency values within temperature stages were maximal 1ms. Since the RMSE for short latency responses calculated with previously collected data was 1.3ms, these delays (<1.3ms) should be assumed as no relevant. Thereby, the hypothesis that inhibition of mechanoreceptors of the foot sole by hypothermia would cause delays on short latency responses should be rejected. Knikou [10] investigated the effects of skin excitation on the soleus H- reflex and flexion reflex in sensory-motor incomplete spinal cord-injured and spinal intact subjects. No early or late flexion reflex responses were noted during sural nerve stimulations in normal subjects. However, based on the results of spinal cord-injured subjects, an interaction between skin receptors and organized spinal interneuronal circuits involving segmental levels of the spinal cord was suggested. Using plantar cutaneous stimulation, another previous study has also described a facilitation of the soleus stretch reflex, presenting earlier onsets when skin around heel was stimulated [3]. Our findings seem to contradict numerous previous studies that indicated a facilitation or inhibition of reflex after core cooling [7] or plantar cutaneous stimulation [2,3,5,10]. The contradiction compared to [7] could be explained by the fact that the subjects were immersed up to the neck in water at 10°C and this procedure may affect not only inputs provided from cutaneous receptors, but also information from the muscles, tendons, ligaments and joint capsules. Regarding studies with plantar cutaneous stimulation, differences regarding the methods can elucidate these controversial results. For instance, we reduced the skin temperature using a foot-shaped thermal-plate, influencing the sensibility of the total area of the plantar foot, while previous studies stimulated only a determined part of the foot. In this regard, a foot sole local-dependency regarding reflex evocation was already demonstrated, producing different reflex responses [3]. Moreover, equally important is the fact that none of the previous studies controlled the validity of data, which shows importance regarding the quality of results. In summary, this study was unable to confirm the participation of skin receptors on short latency responses, since no relevant delays of the Achilles tendon reflex were found after inhibition of mechanoreceptors by cooling. Further studies are intended to clarify the role of plantar cutaneous afferents in modulation of the stretch reflex, as well as the role of skin inputs on balance.

CONCLUSIONS

This study expected delays of short latency responses after foot sole skin cooling as inhibition of plantar mechanoreceptors. Significant delays in SO were found, however they should be assumed as not relevant. The controversial results compared to previous studies can be explained by the use of different methods. Further studies are planned to clarify the association between afferent inputs of the foot sole and reflex responses, as well as the role of afferent inputs on body balance.

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Table 1: Short latency responses (SLR) [ms]: Mean ± Standard Deviation.

	Stage I_25°C	**Stage II_12°C**	**Stage IIIa_0°C**	**Stage IIIb_0°C**
GM	29.4 ±3.2	29.7 ±3.0	29.5 ±3.0	29.5 ±3.1
GL	27.2 ±3.1	27.1 ±3.1	27.4 ±3.2	27.5 ±2.5
SO	29.0 ±5.7*	29.1 ±5.9†	29.3 ±5.7	30.2 ±4.1*†

Significant differences: *Stages I and IIIb (p=0.034); † Stages II and IIIb (p=0.015).