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Research paper

Influence of emotional stimuli on lower limb cutaneous reflexes during human gait

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ABSTRACT

Previous research has shown that cutaneous reflexes are modulated when walking with a threat to stability. It is unclear if this reflex modulation is purely related to the context of the imposed threat or if emotional changes associated with the threat exert an independent influence on reflex excitability. This study investigated the influence of emotional stimuli on lower limb cutaneous reflexes during treadmill walking. Twenty-eight healthy young adults walked at a self-selected pace while viewing pictures that manipulated emotional arousal and valence (confirmed with electrodermal and self-report measures). Throughout each trial, cutaneous reflexes were evoked by electrically stimulating the sural nerve at heel contact, mid-stance, or toe off. Surface electromyography of the ipsilateral soleus (SOL), medial gastrocnemius (MG), tibialis anterior (TA), biceps femoris (BF), and vastus lateralis (VL) was recorded to assess reflexes. Highly arousing pictures, independent of valence, significantly facilitated TA, and trended toward facilitating SOL and BF reflexes during mid-stance. Unpleasant pictures, independent of arousal, significantly reduced reflex amplitudes in BF during mid-stance and TA during toe off. While changes in background muscle activity and step cadence were observed, they did not correlate with reflex changes. This study provides the first evidence that emotional stimuli exert an independent influence on cutaneous reflex excitability during gait. As cutaneous reflexes contribute to stability during gait, these findings support the notion that emotional state influences important sensorimotor processes underlying balance control.

1. Introduction

During walking, electrically stimulating cutaneous afferents innervating the foot evokes functional reflexes in the lower limbs [1]. These reflexes are highly modifiable; they are modulated throughout the gait cycle [1–3] and are sensitive to changes in task [4–7] and anticipation [8,9]. Cutaneous reflexes have also been shown to be sensitive to postural threat [10,11]. When walking with the threat of either a sagittal trunk perturbation [10] or potential trip (via sudden barrier in front of the foot dorsum [11]), cutaneous reflexes are facilitated. While it was suggested that this reflex modulation is primarily context-dependent and not due to a generalized increase in arousal [10,11] this could not be confirmed since individuals' emotional and autonomic response to threat was not recorded. Thus, it remains unclear if individuals' emotional state contributes to changes in cutaneous reflex excitability.

Previous research has shown that a threat to balance, in the form of an unexpected platform tilt or translation, elicits a significant emotional response, such that individuals are more anxious and physiologically aroused [12,13]. When threatened in this manner, both proprioceptive [12] and vestibular [13] reflexes are facilitated and the extent of this facilitation appears to correlate with the strength of the emotional response [13]. In addition, reflex changes have also been evoked by presenting individuals with emotionally charged pictures [14,15], with highly arousing pictures facilitating stretch reflexes [14] and unpleasant pictures facilitating startle reflexes [15]. Therefore, since it is known that threat influences emotional state, and emotional state can influence reflex excitability, we hypothesize that a task-irrelevant emotional stimulus may contribute to changes in cutaneous reflexes during gait.

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The current study investigated if changes in emotional state influence the excitability of lower limb cutaneous reflexes independent of any threat to balance. Pictures from the International Affective Picture System (IAPS; [16]) were presented to participants while they walked unobstructed at a self-selected speed on a treadmill. Pictures were selected to manipulate emotional arousal (low/high) and valence (pleasant/unpleasant) as these dimensions of emotion have been shown to have distinct influences on standing posture [17], gait [18], and reflex excitability [14,15]. It was hypothesized that cutaneous reflexes would be facilitated when viewing highly arousing [12–14] and/or unpleasant pictures [15].

2. Methods

2.1. Participants

Twenty-eight healthy young adults (mean age = 23.32 ± 4.01 years; 15 females) volunteered to participate in this study. Participants reported no known neurological or musculoskeletal disorders that could influence their walking. All procedures were cleared by the University of British Columbia Clinical Research Ethics Board and participants provided written informed consent.

2.2. Manipulation of arousal and valence

Pictures used to manipulate emotional arousal and valence were the same as a previous investigation [17], which created four distinct picture conditions: 1) low arousal-pleasant (LA-P), 2) low arousal-unpleasant (LA-N), 3) high arousal-pleasant (HA-P), and 4) high arousal-unpleasant (HA-N).[1] Picture conditions were presented in blocks (15 pictures repeated twice in the same order, 8 s per picture; total duration = 4 min) on an LCD monitor (width = 112 cm; height = 63 cm) positioned 120 cm in front of the participant at eye level.

2.3. Procedures

Participants completed a total of five trials of treadmill walking. To familiarize participants with the protocol and limit possible first trial effects [19] and anxiety associated with the electrical stimulus, a common first trial with neutral pictures was completed (data not analyzed) [17]. The remaining four experimental trials were randomized to minimize possible order effects. For each trial, participants walked barefoot at a self-selected speed (consistent across all trials; range = 2.7–4.0 km/h) with their arms crossed. This was done for one minute before any pictures were presented to ensure all reflexes were evoked during steady state gait and the electrodermal response associated with gait initiation had subsided. Participants were instructed to remain quiet and focused on the pictures until the pictures stopped. Five minutes of rest were given after each trial to washout residual effects of the previously viewed pictures.

2.4. Sural nerve stimulation

Cutaneous reflexes were elicited by electrically stimulating the right sural nerve (Vmax = 300 V; DS7A Constant Current Stimulator, Digitimer, UK) with a 2 cm-wide bipolar bar electrode positioned along the nerve at the level of the lateral malleolus. The nerve was stimulated with electrical pulse trains (5 × 1 ms square-wave pulses at 200 Hz) at an intensity 2 x radiating threshold (RT) [3,10,11]. Stimuli were evoked intermittently and a custom random number probability algorithm (Spike2, CED, UK) triggered stimuli step-by-step either at heel contact, mid-stance, or toe off (with a 10% chance of receiving no stimulation), with phases of the gait cycle tracked using force sensitive resistors secured to the ipsilateral heel and toe (FSR 402, Interlink Electronics, USA). There was always one non-stimulated step cycle after each stimulus. Approximately 20–30 stimuli were elicited at each gait phase of interest (heel contact, mid-stance, and toe off) throughout each trial.

Prior to completing the first trial, participants walked at their self-selected pace for ∼5 min to ensure the stimulating electrode was secured comfortably and RT remained stable. If RT changed significantly after this period or the neutral condition, the stimulus intensity was adjusted accordingly prior to the experimental conditions. RT was reassessed with the participant standing quietly after each condition. If RT differed by more than 20% for any one condition, those data were excluded from analysis; this happened for only one participant.

2.5. Measures

Surface electromyography (EMG) was recorded (sampled: 3000 Hz; band-pass filtered online: 10–1000 Hz(Telemyo 2400R G2, Noraxon, USA); and A–D sampled: 1000 Hz (Power1401 CED, UK)) from the ipsilateral soleus (SOL), medial gastrocnemius (MG), tibialis anterior (TA), biceps femoris (BF), and vastus lateralis (VL). Electrodermal activity (EDA) was recorded from electrodes on the thenar and hypothenar eminences of the non-dominant hand as an indicator of physiological arousal (sampled: 100 Hz; 2502SA, CED, UK, $n = 16$; EDA100c, BioPac, USA, $n = 7$). From the electrodermal data, mean EDA during each trial was calculated. Due to technical issues, electrodermal data were not available for 5 participants.

Following each 4 min trial, participants were asked to rate the block of pictures in terms of how pleasant (valence scale) and emotionally arousing (arousal scale) they were using the Self-Assessment Manikin (SAM; [20]). The SAM valence and arousal scales are single item 9-point Likert scales; higher scores reflect pictures being perceived as more pleasant and arousing, respectively.

2.6. Reflex analysis

To measure cutaneous reflex amplitude, EMG data for all stimulated and non-stimulated steps were trigger averaged to each gait phase of interest (event markers generated from force sensitive resistor data). Trigger averaged non-stimulated data were subtracted from the corresponding stimulated data to create a pure reflex trace (Fig. 1a and b) [2,3]. To determine reflex onset, a point-by-point ± 4 standard error (SE) threshold based on the corresponding non-stimulated EMG was calculated. Reflex onset and end were defined as the times when the pure reflex trace exceeded and fell back within this threshold for at least 7 of 10 ms, respectively (illustrated in Fig. 1b). Furthermore, onset latency had to occur within a pre-defined medium to late latency window (70–130 ms post-stimulus). Both reflex onset and end were confirmed visually. In the event that two or more distinct reflex waveforms were identified within the detection window, we used visual inspection to choose the larger and more consistent waveform from the four conditions to analyze; when clear differences were not apparent upon visual inspection, the earlier waveform was analyzed. Generally, within-subject reflex onset/end time variance was negligible for any given muscle at each gait phase, so a subject-specific measurement window was set based on the earliest detected reflex onset and latest reflex end across the four picture conditions for each muscle at each gait phase (Fig. 1c). This was done if at least one reflex was detected across the four picture conditions. Data were not analyzed if no reflexes were detected across all four conditions. Reflex amplitude was calculated as the integrated

[1] IAPS pictures used: LA-P: 2035,5760,1610,2370,5551,1620,5200,5811,2360,5010,5891,2304,1604,5725,5779; LA-N: 9220,9000,2750,9265,9280,9342,9331,9290,9330,9291,9832,2455,9001,9471,2753; HA-P: 8030,4681,8492,4668,5621,4659,8186,4670,8370,4664,8490,4810,8080,4652,8185; HA-N: 3400,6230,2730,6563,3213,3030,6550,6312,9908,8485,6540,9250,3212,6300,3150.