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# Influence of posture on blink reflex prepulse inhibition induced by somatosensory inputs from upper and lower limbs

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ABSTRACT

*Background:* Prepulse inhibition (PPI) is a neurophysiological phenomenon whereby a weak stimulus modulates the reflex response to a subsequent strong stimulus. Its physiological purpose is to avoid interruption of sensory processing by subsequent disturbing stimuli at the subcortical level, thereby preventing undesired motor reactions. An important hub in the PPI circuit is the pedunculopontine nucleus, which is also involved in the control of posture and sleep/wakefulness.

*Objective:* To study the effect of posture (supine versus standing) on PPI, induced by somatosensory prepulses to either upper or lower limb. PPI was measured as the percentage inhibition of the blink reflex response to electrical supraorbital nerve (SON) stimulation.

*Methods:* Sixteen healthy volunteers underwent bilateral blink reflex recordings following SON stimulation either alone (baseline) or preceded by an electrical prepulse to the median nerve (MN) or sural nerve (SN), both in supine and standing. Stimulus intensity was 8 times sensory threshold for SON, and 2 times sensory threshold for MN and SN, respectively. Eight stimuli were applied in each condition.

*Results:* Baseline blink reflex parameters did not differ significantly between the two postures. Prepulse stimulation to MN and SN caused significant inhibition of R2. In supine but not in standing, R2 was significantly more inhibited by MN than by SN prepulses. In standing, SN stimulation caused significantly more inhibition of R2 than in supine, while the inhibition caused by MN prepulses did not differ significantly between postures.

*Significance:* PPI induced by lower limb afferent input may contribute to postural control while standing.

## 1. Introduction

Prepulse inhibition (PPI) is a neurophysiological phenomenon whereby a weak stimulus, which does not produce a reflex response by itself, inhibits the reflex response to a subsequent high intensity stimulus. In case of the blink reflex, PPI may occur with somatosensory or auditory stimuli applied at appropriate interstimulus intervals (ISIs) [1]. PPI is a paradigmatic sensorimotor gating process aiming at avoiding interruption of sensory processing by subsequent disturbing stimuli at a subcortical level and at preventing undesired motor reactions [2]. Evidence suggests an important role of cholinergic neurons in the pedunculopontine nucleus (PPN) for PPI [3].

As part of the reticular activating system, the PPN plays a role in sleep-wake cycle and arousal control, as well as in mediating PPI, as demonstrated in animal and human studies [3]. The PPN acts within a complex brainstem network in modulating inputs coming from the periphery and filtering the ascending outflow to the intralaminar thalamic nuclei [3]. Furthermore, cholinergic PPN neurons modulate gait and postural control [3] and have become a target for deep brain stimulation in Parkinson's disease patients with severe gait disorder [3].

We hypothesized that if the PPN participates in control of somatosensory information, the amount of PPI on potentially disturbing stimuli may be influenced by posture. In this study, our aim was to assess the effect of supine versus upright posture on PPI elicited by somatosensory prepulses to either the upper or the lower limb on blink reflexes evoked by electrical supraorbital nerve (SON) stimulation. We considered that the postural change from supine to standing mostly concerns the processing of afferents from the lower limbs and therefore we would expect a greater effect of postural change on PPI for inputs from the lower limbs than from the upper limbs.

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## 2. Methods

### 2.1. Participants

Sixteen healthy right-handed volunteers (10 females, age 31.4 ± 8.6 years) participated after giving written informed consent to the study, which was approved by the local institutional review board. Subjects were investigated in a silent room at a comfortable room temperature.

### 2.2. Stimulation and recording

All data were obtained with routine electrodiagnostic equipment (Viking EDX, Natus, Middleton, WI, USA). Blink reflexes were elicited by electrical stimuli as described elsewhere [4]. The stimulator probe was manually controlled by the examiner without the subjects' knowing when stimulation would occur. Stimulus intensity was 8 times sensory threshold.

Electrical prepulse stimuli (constant current square-wave pulses of 0.2 ms duration, 2 times sensory threshold) were delivered either to the median nerve (MN) with ring electrodes placed at the proximal and middle phalanx of the dominant index finger or with surface electrodes to the ipsilateral sural nerve (SN) just below the lateral malleolus.

Sensory threshold was defined as the minimum stimulus intensity perceived in at least 4 out of 8 consecutive stimuli, and was established for all three stimulus locations.

Single sweeps of electromyographic activity of the orbicularis oculi muscle were recorded bilaterally with self-adhesive disposable electrodes attached to the skin, the active electrode in the middle portion of the muscle below each eye, and the reference electrode lateral to the outer canthus. The electromyographic signal was amplified (x1000), band-pass filtered (30 −3000 Hz), and rectified.

### 2.3. Procedures

SON stimuli were applied alone in control trials, or preceded by a prepulse stimulus at fixed ISIs in test trials. Control and test trials were presented in two experimental conditions: in the condition 'supine', subjects lay supine on a comfortable bed, with arms lying relaxed beside the body. In the condition 'standing', subjects stood with their feet apart at the individual's preferred distance and with arms aligned next to the body. Prepulse stimuli were applied at two different sites, MN and SN, with ISIs adjusted such that MN and SN inputs would reach the brainstem at approximately the same time. The ISI for a prepulse stimulus to MN was chosen to be 100 ms according to previous literature [1,5]. The ISI for SN prepulses was chosen to be 116 ms, as 16 ms was the estimated difference in afferent time between arm and leg based on somatosensory evoked potential studies [6]. The experimental conditions (supine and standing) were run in random order, counterbalanced among subjects. Control and test trials were presented up to recording 8 artifact-free control and test trials for each posture and prepulse site. Subjects remained silent and relaxed in particular with respect to their facial muscles, with eyes open, attending to the stimuli. Subjects evaluated the level of unpleasantness of SON stimulation based on a numerical rating scale (NRS, 1 = least, 10 = most unpleasant).

### 2.4. Data analysis and statistics

We measured latency and amplitude of the ipsilateral R1 component of the blink reflex, as well as latency and area-under-the-curve (henceforth "area") of the ipsilateral R2 and contralateral R2c components in each single rectified trace in control and test trials. We then averaged raw data from 8 control trials to SON stimuli alone, and from 8 test trials obtained following either MN or SN prepulses, per subject and posture, and ascertained normal data distribution of all parameters with Kolmogorov-Smirnov testing.

First we examined whether differences occurred in control blink reflexes between the two postural conditions, supine and standing, using paired t-tests. Then we assessed the expected effects of prepulse stimuli using paired t-tests for comparison of control and test trials separately for each condition and prepulse site. Because of multiple t-tests, we applied Bonferroni's correction resulting in a significant *P*-value of 0.05/3 = 0.0167 (control trials in supine were compared to test trials in supine following MN prepulses, to test trials in supine following SN prepulses; and to control trials in standing; hence, control trials in supine were tested thrice; likewise, control trials in standing were compared to test trials in standing following MN prepulses, to test trials in standing following SN prepulses, and to control trials in supine; hence, control trials in standing were also tested thrice).

To determine whether there were different effects according to posture or prepulse site, we normalized all data: We arbitrarily assigned 100% to the mean value obtained for each subject and parameter in control trials in the supine position, and represented all individual values (in control and test trials) as percentages. These relative values were then averaged per subject, per condition (supine, standing), and per prepulse site (MN, SN), in order to calculate group means and standard deviations for latency and magnitude of R1, R2, and R2c. PPI size for each prepulse site and condition was, therefore, expressed as the percent reduction of the response area with respect to control trials in such a way that smaller PPI values represent more inhibition. Comparative statistics were performed on these percentage values in test trials only by using a 2-factor repeated measures ANOVA for posture (two levels: supine, standing) and prepulse sites (two levels: MN, SN). Paired t-tests were used in post-hoc analyses to follow-up on significant differences. The level of significance was set at $p < 0.05$.

## 3. Results

All subjects completed the experiments without difficulty. Sensory thresholds were 1.2 ± 0.2 mA for SON, 1.8 ± 0.4 mA for MN, and 3.3 ± 1.1 mA for SN stimulation. All blink reflex parameters (R1 latency and amplitude, R2 latency and area, R2c latency and area) were normally distributed. Paired t-tests of raw data showed no significant differences between supine and standing positions in any control blink reflex parameter (Table 1).

### 3.1. Prepulse effects by MN and SN stimuli

Prepulse effects were observed in both postures for both prepulse sites. Fig. 1 shows representative examples recorded in one subject. Prepulse stimuli to MN led to a significant reduction of R2 and R2c area, and a significant increase in R2 and R2c latency, in both supine and standing. In standing, MN prepulses also caused significant facilitation of R1 ampitude (Table 1).

Prepulses to SN caused a significant reduction of R2 and R2c area in both supine and standing, but no significant changes in R1 amplitude or latency (Table 1).

### 3.2. Differences in prepulse effects relative to prepulse site

A 2-factor repeated measures ANOVA revealed a significant main effect of prepulse site (MN, SN), but not of posture (supine, standing), and a significant interaction between prepulse site and posture, on the area of R2 and R2c, respectively (Table 2). There was also a significant main effect of prepulse site, but not of posture, and no interaction between prepulse site and posture, on latency of R2 and R2c and amplitude of R1 (Table 2).

In supine posture, MN prepulses were more effective in suppressing R2 and R2c area, as well as in delaying R2 and R2c latencies, as compared to SN stimuli. There was no significant difference in R1 amplitude facilitation (Table 3). In contrast, in standing, MN prepulses were more effective in increasing R1 amplitude, and in shortening R2 and R2c

**Table 1**
Comparison of values obtained in control trials versus test trials with prepulses delivered to the median nerve at the index finger (MN) or the sural nerve below the ankle (SN) in the two postures, supine and standing. Figures are group mean values of individual means (standard error within parenthesis) for absolute data in control and test trials. *P* values < 0.0167 indicating statistically significant differences are in bold.

| | | R1 latency [ms] | R1 amplitude [μV] | R2 latency [ms] | R2 area [μVms] | R2c latency [ms] | R2c area [μVms] |
|---|---|---|---|---|---|---|---|
| **control supine** | mean (SE) | 10.7 (0.3) | 236 (34) | 29.3 (0.7) | 1859 (195) | 30.1 (0.8) | 1580 (139) |
| **MN supine** | mean (SE) | 10.6 (0.3) | 282 (52) | 33.8 (0.9) | 623 (100) | 34.3 (1.1) | 362 (63) |
| *MN supine vs control* | *P* | 0.498 | 0.201 | **0.0000** | **0.0000** | **0.0003** | **0.0000** |
| **SN supine** | mean (SE) | 10.6 (0.2) | 236 (28) | 30.7 (0.8) | 1178 (134) | 31.0 (0.8) | 814 (80) |
| *SN supine vs control* | *P* | 0.558 | 0.989 | 0.027 | **0.0002** | 0.084 | **0.0000** |
| **control standing** | mean (SE) | 10.5 (0.3) | 185 (34) | 29.4 (0.8) | 1875 (176) | 30.3 (0.9) | 1573 (121) |
| **MN standing** | mean (SE) | 10.4 (0.3) | 301 (51) | 34.1 (1.0) | 777 (116) | 34.8 (1.3) | 532 (125) |
| *MN standing vs control* | *P* | 0.869 | **0.0033** | **0.0001** | **0.0000** | **0.0025** | **0.0000** |
| **SN standing** | mean (SE) | 10.7 (0.3) | 215 (40) | 31.2 (0.9) | 895 (103) | 31.7 (1.0) | 697 (89) |
| *SN standing vs control* | *P* | 0.274 | 0.183 | **0.013** | **0.0000** | 0.066 | **0.0000** |
| *control supine vs control standing* | *P* | 0.218 | 0.095 | 0.690 | 0.894 | 0.722 | 0.935 |

latencies, than SN prepusles, but there was no significant difference in prepulse inhibition of R2 and R2c area (Table 3).

### 3.3. Differences in prepulse effects relative to posture

Post-hoc analyses showed significantly more suppression of R2 and R2c area by SN prepulses in standing than in supine, while PPI following MN prepulses did not differ significantly between supine and standing (Fig. 2, Table 3).

### 3.4. Prepulse effects on the level of perceived SON stimulation intensity

In the supine position, both MN and SN prepulses reduced the level of perceived unpleasantness associated with SON stimulation, based on NRS scores, from 3.5 ± 1.5 in control trials to 2.6 ± 1.5 with MN prepulses ($P = 0.002$), and to 2.8 ± 1.2 with SN prepulses ($P = 0.000$).

Similarly while standing, both MN and SN stimulation reduced NRS scores from 3.8 ± 1.4 to 2.8 ± 1.3 with MN prepulses ($P = 0.001$),

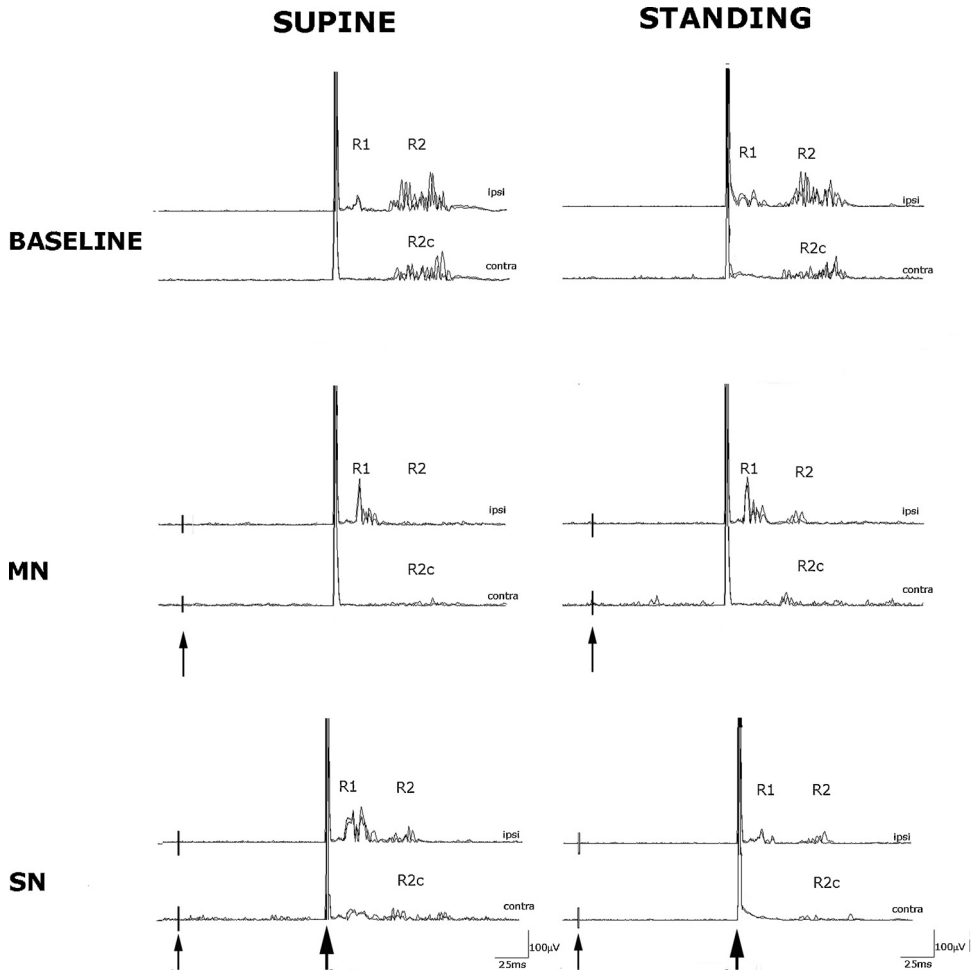


**Fig. 1.** Representative examples of blink reflex responses in a healthy female subject in the baseline condition and with prepulse stimulation to the median nerve at the dominant index finger (MN) or sural nerve below the ankle (SN), in supine and standing posture. Note the increase in R1 amplitude and the decrease in ipsilateral R2 and contralateral R2c area with prepulse stimulation. Thick arrows indicate SON stimuli; thin arrows indicate prepulse stimuli.

**Table 2**
Statistical results of repeated measures ANOVA for all assessed blink reflex parameters in test trials expressed as percentage of individual mean control values obtained in the supine position; posture = supine vs. standing; PPI = prepulse inhibition; PPI site = prepulses applied to the median nerve at the index finger vs. the sural nerve below the ankle. Significant results are in bold.

| Parameter | Factor | |
|---|---|---|
| R1 latency | Posture | $F_{1,15} = 1.859$, $P = 0.193$, $\eta_p^2 = 0.110$ |
| | PPI site | $F_{1,15} = 2.226$, $P = 0.156$, $\eta_p^2 = 0.129$ |
| | Posture * PPI site | $F_{1,15} = 0.233$, $P = 0.636$, $\eta_p^2 = 0.015$ |
| R1 amplitude | Posture | $F_{1,15} = 0.007$, $P = 0.935$, $\eta_p^2 = 0.000$ |
| | **PPI site** | **$F_{1,15} = 6.311$, $P = 0.024$, $\eta_p 2 = 0.296$** |
| | Posture * PPI site | $F_{1,15} = 2.182$, $P = 0.160$, $\eta_p^2 = 0.127$ |
| R2 latency | Posture | $F_{1,15} = 1.209$, $P = 0.289$, $\eta_p^2 = 0.075$ |
| | **PPI site** | **$F_{1,15} = 16.889$, $P = 0.001$, $\eta_p 2 = 0.530$** |
| | Posture * PPI site | $F_{1,15} = 0.271$, $P = 0.610$, $\eta_p^2 = 0.018$ |
| R2 area | Posture | $F_{1,15} = 1.138$, $P = 0.303$, $\eta_p^2 = 0.071$ |
| | **PPI site** | **$F_{1,15} = 15.818$, $P = 0.001$, $\eta_p 2 = 0.513$** |
| | **Posture * PPI site** | **$F_{1,15} = 21.823$, $P = 0.000$, $\eta_p 2 = 0.593$** |
| R2c latency | Posture | $F_{1,15} = 2.081$, $P = 0.170$, $\eta_p^2 = 0.122$ |
| | **PPI site** | **$F_{1,15} = 11.368$, $P = 0.004$, $\eta_p 2 = 0.431$** |
| | Posture * PPI site | $F_{1,15} = 0.112$, $P = 0.742$, $\eta_p^2 = 0.007$ |
| R2c area | Posture | $F_{1,15} = 0.116$, $P = 0.738$, $\eta_p^2 = 0.008$ |
| | **PPI site** | **$F_{1,15} = 13.479$, $P = 0.002$, $\eta_p 2 = 0.473$** |
| | **Posture * PPI site** | **$F_{1,15} = 9.620$, $P = 0.007$, $\eta_p 2 = 0.391$** |

and to 2.8 ± 1.6 with SN prepulses ($P = 0.008$).

There were no significant differences between MN and SN prepulses (supine: $P = 0.216$, standing: $P = 1.000$), nor between supine and standing (MN prepulses: $P = 0.388$; SN prepulses: $P = 1.000$), with respect to NRS scores.

## 4. Discussion

The main findings of the present study are: (i) prepulse effects on blink reflex are more robust for upper limb than for lower limb afferents when lying supine; (ii) the size of PPI from lower limb afferents increases significantly when standing. These findings indicate that there is a strong influence of posture on prepulse effects from lower limb afferents, in such a way that, when standing, PPI induced by SN stimuli nearly equalled that induced by MN prepulses.

### *4.1. Differences in PPI to upper versus lower limb prepulses in supine and standing*

The conspicuous preponderance of PPI induced by prepulses applied to MN compared to those delivered to SN in the supine position may in part be due to different properties and effectiveness of the somatosensory afferent volleys from upper and lower limb nerves. As demonstrated by previous authors [7–9], the afferent volley generated from electrical stimulation of the upper limbs is mainly constituted by inputs

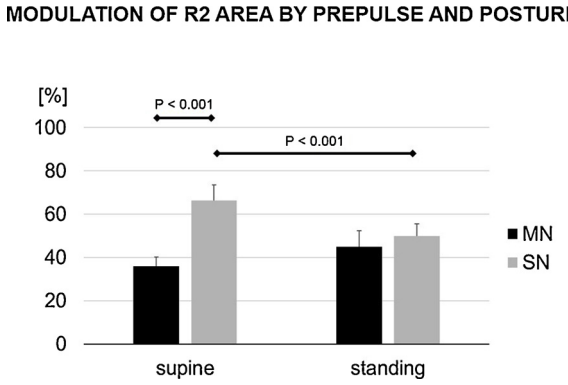


**Fig. 2.** Normalized group data for R2 area values in test trials, for both postures (supine, left, standing, right) and for both prepulse sites, median nerve (MN, black columns) and sural nerve (SN, gray columns). The values for both postures and for both prepulse sites represent percentages of each individual's mean value in control trials. Whiskers represent standard error.

from cutaneous afferents and likely produces a more homogeneous and short-latency afferent volley to reach the central nervous system. The afferent volley from the lower limb has a variegated composition including cutaneous and muscle afferents, and because of the longer distance arrives at the central nervous system with more temporal dispersion.

Another possible explanation for the different PPI size following upper versus lower limb nerve afferent input to the cerebral cortex may be related to the cortical somatosensory representation, which is much larger for the index finger than for the lateral foot [10–13]. However, prepulses applied to the elbow had an effect on the blink reflex similar to prepulses to MN when delivered at 2 times sensory threshold intensity (personal observation). Furthermore, considering that PPI is regulated rather by frontal projections to the brainstem than by efferents from the somatosensory cortex [14] it seems that the size of cortical somatosensory representation is not critical.

Differences in elicitation of brainstem reflexes between nerve afferents from upper and lower limbs was already shown in a study of the somatosensory startle reflex [15]. In that study, the authors found that responses in orbicularis oculi muscle were larger and of shorter latency following high intensity electrical stimuli to upper as compared to lower limb nerves. In contrast, responses in sternocleidomastoid muscle were more prominent to lower limb than to upper limb stimulation. Exteroceptive and proprioceptive afferent information from the lower limbs, together with vestibular and visual inputs, allow on-line control of posture during standing and walking [16–19]. It makes sense, therefore, that, as Alvarez-Blanco et al. [15] demonstrated, the afferent volley generated by stimuli to the lower limb nerves induces relatively little activation of periocular muscles, as visual inputs may be needed to maintain stability when a strong, potentially dangerous stimulus is felt

**Table 3**
Figures are the mean values (and one standard error within parenthesis) for average data in test trials in percentage of the mean control in the supine position. *P* values < 0.05 indicating statistically significant differences are in bold.

| | | R1 latency | R1 amplitude | R2 latency | R2 area | R2c latency | R2c area |
|---|---|---|---|---|---|---|---|
| **MN supine** | mean (SE) | 99.0 (1.2) | 119.6 (11.2) | 115.8 (2.5) | 36.0 (4.3) | 114.4 (3.2) | 27.0 (3.9) |
| **MN standing** | mean (SE) | 97.1 (1.3) | 129.1 (18.9) | 116.6 (3.2) | 44.8 (7.5) | 115.7 (4.0) | 35.1 (6.2) |
| **SN supine** | mean (SE) | 100.6 (1.4) | 98.9 (11.8) | 104.7 (2.0) | 66.3 (7.3) | 103.5 (2.8) | 56.8 (8.3) |
| **SN standing** | mean (SE) | 99.7 (1.4) | 90.2 (9.3) | 106.8 (2.7) | 49.8 (5.8) | 105.9 (3.1) | 46.0 (6.7) |
| **MN vs SN – supine** | *P* | 0.424 | 0.150 | **0.000** | **0.000** | **0.002** | **0.000** |
| **MN vs SN – standing** | *P* | 0.057 | **0.009** | **0.009** | 0.402 | **0.024** | 0.136 |
| **supine vs standing – MN** | *P* | 0.281 | 0.219 | 0.707 | 0.111 | 0.605 | 0.153 |
| **supine vs standing – SN** | *P* | 0.353 | 0.293 | 0.199 | **0.000** | 0.146 | **0.027** |

MN = prepulse applied to the median nerve at the index finger, SN = prepulse applied to the sural nerve below the ankle, SE = standard error of means.

in lower limbs.

Our findings concur well with previous observations reported above: SN prepulses suppressed R2 area in standing more than in lying position, a phenomenon that could contribute to the inhibition of the response to the startling somatosensory stimulus. Once more, reduced blinking could be convenient when an unsuspected stimulus arrives in the feet while standing.

An alternative physiological explication of the disparate effectiveness of somatosensory inputs from upper or lower limbs in the two postures could be that in the stance phase the volume of afferent inputs from the feet increases considerably due to the activation of tactile and proprioceptive receptors that contribute to posture and balance control (including inputs from foot sole mechanoceptors, load receptors, muscle spindles, Golgi organ receptors and others).

It could be therefore possible that the increased information flow from lower limbs while standing undermines at least partially all the other afferent inputs converging in brainstem circuits. Nevertheless, we found facilitation of R1 while standing, which indicates the arrival of the excitatory phase that has been described to briefly preceed PPI [1,20]. We must consider, therefore, that the inputs from the lower limbs reached the brainstem circuits related to PPI in their integrity.

### 4.2. Convergence of both postural control and prepulse inhibition in the pedunculopontine nucleus: the hypothesis of "central" tuning

Postural control and alertness converge on brainstem structures that have been found to be involved in PPI: locus coeruleus and PPN [3,21–23]. The paradigm of negative interference in posture-cognitive dual-tasks has been extensively investigated in the past. Because of the shared utilization of the same "limited" neural resources, an inferior motor performance is observed when simultaneously focusing on a demanding attentional-cognitive task or vice versa [24–30]. Various studies demonstrated that in dual tasks involving both posture and cognition the subject´s performance depends on the preferential allocation of resources either in the cognitive domain or in postural control [31–35].

On the other hand, there is a „positive "interference between upright posture and wakefulness/arousal: we sleep in supine position; in contrast, we are most awake and alert while standing. Neurophysiological measures and cognitive assessments indicate increased neural activity in upright compared to supine position. In sleep-deprived subjects, upright posture increased sustained attention and attenuated electroencephalographic (EEG) theta activity [36]. A shift towards faster EEG frequencies in upright posture has been extensively demonstrated [36–39]. On the contrary, the supine position stimulates cardiopulmonary and arterial baroreceptors, thus reducing sympathetic system activation and decreasing cortical excitability [40–43]. Notably, a posture-dependency of arousal level and awareness has been demonstrated in vegetative and minimally conscious state patients by means of behavioral scales [44,45] and quantitative EEG analysis [46,47], which underscores the use of early verticalization in neurorehabilitation of brain injured patients [48,49].

It has previously been demonstrated that the inhibitory effect of a prepulse could be due to the attentional shift towards the prepulse sensory stimulus [50,51]. However, in a recent study, it has been found that PPI of the blink reflex was maintained the same despite subjects focusing their attention to either the prepulse or to the reflex-eliciting stimulus [52].

Interstingly, in contrast to disparate blink reflex prepulse modulation according to prepulse site and posture, the associated decrease in conscious perception of unpleasantness of SON stimuli did not differ significantly among postures and prepulse sites.

Finally, another explanatory hypothesis for the observed differences in blink reflex PPI related to posture on one hand and prepulse site on the other hand could be tuning of the filtering action exerted by PPN neurons upon afferent sensory information flow in a top-down manner. Thus, PPI might be modulated as a function of relevance of the stimuli. In supine, stimuli originating in upper limbs may be more relevant, while in standing, it seems reasonable that greater functional salience is preconsciously attributed to stimuli deriving from the lower limbs. The PPN may mediate such posture-related subcortical sensory information processing, which may be relevant for the adjustment of posture and maintenance of balance control.

### 4.3. Limitations

One limitation of the study is the small sample size, yet we were able to demonstrate a physiological observation that provides relevant information on posture-related changes in somatosensory integration at the subcortical level.

Another limitation is that the investigations in the standing posture were done with no specific control of the subject's balance. The tests were performed with subjects standing firmly on both legs, without holding onto anything or leaning against the wall. It is conceivable that PPI to inputs from the lower limbs adapts to the ongoing balance control activity, i.e., its size (the amount of inhibition of blink reflex reactions) may depend on the combination of afferent inputs reaching the central nervous system at any given moment. It is known that balance is kept by continuously performing small reflexive contractions in different muscle groups, depending in part on the afferent cutaneous input [53,54]. Therefore, our findings demonstrate only an averaged effect of posture on blink reflex PPI. More detailed studies should take into account the precise timing of the prepulse stimulus in relation to balance during quiet stance and various postural demands in other conditions.

Finally, despite clear evidence that sensory input from the feet causes larger inhibition of the blink reflex while standing than when supine, our data do not suffice to sort out the exact mechanisms underlying this phenomenon.

### 4.4. Conclusion

The present study shows that posture affects the size of PPI. Increased PPI from lower limb afferents while standing may contribute to postural control, as this prevents inconvenient motor reactions. The PPN is suggested to be an important site for regulation of posture-related PPI changes.

## Author contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

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