Soleus T-reflex amplitude modulation when standing humans adopt a challenging stance

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Abstract

The amplitude of the short latency EMG response to soleus muscle stretch produced by a mechanical tendon tap (T-reflex) was determined when subjects stood in a stable stance position and a challenging stance with a reduced base of support in the sagittal plane (tandem stance). Most subjects (14 of 19) decreased mean T-reflex amplitude when in the tandem stance position, compared to the stable stance (mean (s)), -13.7% (31%). All nine subjects who performed the tandem stance without lightly touching support boxes, decreased their T-reflex amplitude in the tandem stance position, -31% (20%), \( p = 0.002 \), Cohen’s d = 1.5.

Ten subjects needed to lightly touch the support boxes with the back of two or three fingers while in the tandem stance. Five of these decreased reflex amplitude while the others increased reflex amplitude, 2.0% (32%). For all subjects, and for the subgroups of those that could, or could not perform the tandem stance without touching support boxes, there was no significant change in soleus or TA bEMG levels. These data demonstrate that the soleus T-reflex is modulated (typically decreased) when a difficult tandem stance is performed. Possible mechanisms of modulation of the T-reflex across the sanding tasks were discussed.
**Introduction**

It has been frequently observed that the soleus Hoffmann (H-) reflex is decreased in amplitude when a person changes from a stable standing position, to a standing position that involves a greater degree of balance challenge with the same level of muscle activation (G. R. Chalmers & Knutzen, 2002; Earles, Koceja, & Shively, 2000; Hoffman & Koceja, 1995; Huang, Cherng, Yang, Chen, & Hwang, 2009; Solopova, Kazennikov, Deniskina, Levik, & Ivanenko, 2003; Tokuno, Taube, & Cresswell, 2009; M. H. Trimble & Koceja, 2001). The decrease in soleus H-reflex amplitude during a challenging standing task is believed to be due to spinal inhibition of the Ia afferent signal to stabilize the posture by preventing the Ia signal (potentially enhanced during the difficult task, see below) from being strong enough to excessively activate spinal motor neurons, while still allowing the enhanced afferent information to be available to higher control centers (Hayashi, Tako, Tokuda, & Yanagisawa, 1992; Hidler & Rymer, 1999; Katz, Meunier, & Pierrot-Deseilligny, 1988; Llewellyn, Yang, & Prochazka, 1990; V. G. Macefield, Gandevia, Bigland-Ritchie, Gorman, & Burke, 1993; McIlroy et al., 2003; Nafati, Rossi-Durand, & Schmied, 2004; Taube et al., 2007). Greater cortical involvement during precision, difficult or novel movements has been indicated by a number of studies (McIlroy et al., 2003; Schmied, Pagni, Sturm, & Vedel, 2000; Schubert et al., 2008; Sibley, Carpenter, Perry, & Frank, 2007; Solopova et al., 2003; Tokuno et al., 2009).

In contrast to the many studies examining soleus H-reflex modulation across different standing tasks, information on how, or if, the soleus stretch reflex is
modulated when a person performs a challenging standing task is sparse. When subjects stood quietly without support, the Achilles tendon stretch reflex was decreased in size, compared to with hand support (Elner, Gurfinkel, Lipshits, Mamasakhlisov, & Popov, 1976). Background electromyographic (bEMG) activity was not measured by Elner and Gurfinkel (Elner et al., 1976) but may be assumed to be similar based on the similar ankle plantar flexor demands in both tasks. For the muscles of the anterior compartment of the leg, removing hand support while standing resulted in an increased muscle spindle response, although muscle stretch reflex response was not measured (Burke & Eklund, 1977). These studies differ from the H-reflex studies above, in that the degree of balance challenge was minimal; standing without hand support was the most challenging task for the subjects. In contrast, H-reflex studies commonly challenge the balance of standing subjects with a reduced base of support in the sagittal plane or by using an unstable surface.

Information obtained by H-reflex studies cannot be assumed to reveal operation and function of the stretch reflex. For example, the soleus H-reflex was depressed during the stance phase of walking compared to sitting or standing, while the stretch reflex was not (Andersen & Sinkjaer, 1999; Sinkjaer, Andersen, & Larsen, 1996), and the H-reflex was depressed more than the T-reflex when the ankle was dorsiflexed (Guissard, Duchateau, & Hainaut, 1988). Similarly, during an attention demanding wrist extensor muscle motor task and when switching from a supine to standing position the H-reflex was inhibited while the stretch or T-reflex was facilitated (Nafati et al., 2004; Shimba, Kawashima, Ohta, Yamamoto, &
Divergent reflex modulation was also observed in the first dorsal interosseous muscle when exerting a force against a unstable inertial load, compared to a stable fixed load; there was no change in the stretch reflex, while the H-reflex was increased (Maluf, Barry, Riley, & Enoka, 2007).

In summary, while much is known about the modulation of the soleus H-reflex across standing balance tasks of increasing challenge, far less is known about the operation of the more physiologic stretch reflex pathway during such tasks. There is the potential for modulation of the spindle sensitivity, even at equivalent muscle activation levels, and possible differences in the spinal modification of stretch versus electrically invoked afferent signals, that would not be revealed in H-reflex studies. The goal of this study was to determine if the amplitude of the sort latency EMG response to soleus muscle stretch produced by a mechanical tendon tap (T-reflex) is modulated when a person performs a challenging standing balance task with a reduced base of support in the sagittal plane.

**Methods**

**Subjects**

Nineteen subjects (11 male, 8 female; age mean ± standard deviation: 24 ± 6 years, age range: 18 - 45 years) with no known neurological, muscular, or gait pathologies participated in this study. Older adults, well-trained athletes, and people with dance or gymnastic experience were not recruited as these characteristics modify soleus reflex function (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; G.R. Chalmers & Knutzen, 2000; Koceja & Kamen, 1988; Nielsen, Crone, & Hultborn, 1993; Taube et al., 2007). All subjects
complied with the requirement that they only consume light food, and no
stimulants or tobacco for two hours prior to testing (Eke-Okoro, 1982). Further, all
subjects reported any medications they were taking and it was verified that none
took any medications that affected the muscular or nervous systems. The
experiments were approved by the Ethics Committee on Human Experiments at
Western Washington University, and all subjects gave their written informed
consent prior to inclusion in the study.

**Experimental Procedure and Data Acquisition**

All measurements were made on the right leg, with surface electrodes placed
and not removed until completion of data collection, in a room isolated from visual
and auditory distractions. Skin at the electrode sites was thoroughly cleaned with a
light abrasive, and EMG recording electrodes (Ag-AgCl, 10 mm in diameter, 3-cm
interelectrode distance) were placed on the soleus, along the midline of the dorsal
aspect of the leg with the proximal electrode 1 cm distal to medial head of the
gastrocnemius, and on the tibialis anterior (TA) muscle, one third of the distance
from the patella to the lateral malleolus (Zipp, 1982). A 26-cm² metal plate ground
electrode was attached to the right wrist. Muscle EMG signals were amplified by
bipolar differential amplifiers with a common mode rejection ratio of 90 dB, and a
frequency bandpass of 10-1000 Hz (Grass P5, West Warwick, RI). The EMG
signals were digitized at 2100 Hz with a 12-bit data acquisition card (Micro 1401,
Cambridge Electronic Designs, Cambridge, UK) and were analyzed using Spike2
software (Cambridge Electronic Designs). The soleus EMG signal was displayed
in a raw format to allow for peak-to-peak measurements of the evoked T-reflex.
EMG response following tendon tap (Toft, Sinkjaer, & Espersen, 1989). The EMG signals were concurrently displayed in a rectified and then smoothed format (all smoothed EMG signals were calculated as each point averaged over the previous 40 millisecond period) to provide feedback to the subject and to allow for measurement of the bEMG level prior to a stimulus.

During all measurements, subjects kept eyes open and looked at a blank computer screen, or at a screen providing EMG feedback (described below) and avoided any muscle contractions, other than those needed to maintain the standing position (Taube, Leukel, & Gollhofer, 2008). It was ensured that the angle of the right ankle was not varied during the experiment due to the dependence of stretch reflexes on ankle angle (Patikas, Kotzamanidis, Robertson, & Koceja, 2004; Weiss, Kearney, & Hunter, 1986).

A random sequence of the two stance positions tested was then assigned to the subject: stable stance (standing with feet spaced at a natural preferred distance apart, with the heel of the left foot in line with the toes of the right foot and both hands placed on the top of solid support boxes on each side of the subject), and tandem stance (standing with the left foot placed directly in front of, and with heel touching the toes of, the right foot, and arms held loosely at the sides). For ten subjects the tandem stance position was so difficult that it could not be performed without a high level of soleus and TA cocontraction and movements of the upper body. These subjects were allowed to place the back of two or three fingers of both hands gently against the vertical sides of the support boxes lateral to them to obtain touch sensation without mechanical support. Even with these
additional points of contact, subjects reported and the researcher observed that
the tandem stance task was still significantly more difficult than the stable stance.

EMG activity was recorded from the soleus while the subject stood in the stable
and then the tandem stance positions for 20 seconds each, and the minimum and
maximum levels of the rectified and smoothed EMG record over 20 random points
in the EMG record were measured. The minimum and maximum EMG levels were
used subsequently to form a target range of soleus bEMG levels for data collection
during the two standing tasks, to ensure that bEMG levels were similar when
measures were made during the two tasks.

A mechanical tendon tapper was adjusted so that it would strike the Achilles
tendon. The force of the strike was adjusted by changing the length of the arc a
hammer swung through. The hammer was a steel bar pivoting on a very low
friction axis with multiple set points of release. A micro switch in the head allowed
a timing pulse to be recorded when the hammer contacted the leg. Pilot studies
determined that the hammer contacted the skin for a duration of 15 ms. The
reliability of the force delivered was determined by having the hammer hit a force
transducer in the same manner with which it hit a subject’s leg. The hitting force
was tested for 20 repeated strikes at each of the two hammer heights (i.e. force)
settings used for this experiment. For the two force levels, the mean ± s and
coefficient of variation were 256 N ± 23 N, 9% and 338 N ± 12 N, 3%. The striking
force for each subject was selected to be the one that produced an obvious stretch
reflex response without discomfort.
In both of the stance positions, the following procedure was followed for each subject. The subject was provided with feedback on the current right soleus and TA rectified and smoothed EMG level by means of a computer monitor positioned directly in front of the subject’s face. The target range of bEMG levels was divided into 10 steps, and the sequence of those steps was randomly assigned as target contraction levels. A target contraction level was presented as a horizontal line on the computer monitor. If the target level was greater than the contraction level the subject was already producing to maintain stance, then the subject performed a right leg ankle plantar flexion contraction so that the feedback bEMG level matched the target level. The plantar flexion forces were always small enough that the ankle angle did not change. If the TA was observed to have more than minimal electrical activity, the subject was asked to reduce the activity before proceeding. When the soleus bEMG level approximately matched the target and had been held steady for at least 1 second, an Achilles tendon tap was delivered. If a muscle contraction above that needed to naturally maintain the stance was required, the subject then relaxed for at least 20 seconds to ensure that no post-voluntary activation depression of the reflex occurred in the subsequent test (Grey et al., 2008; Pierrot-Deseilligny & Mazevet, 2000). This process was repeated until a minimum of 20 measures of the T-reflex had been recorded for the stance position, with these measures varying in soleus bEMG level. The total amount of time spent practicing the tandem stance position prior to the actual measurements did not exceed five minutes.
Data Analysis

For each mechanical stimulation, the peak-to-peak amplitude of the T-reflex EMG response (Figure 1) and the mean rectified and smoothed soleus and TA bEMG levels over 0.1 seconds prior to the stimuli were determined. In all subjects the tandem stance position was more difficult to maintain than the stable stance position, resulting in greater co-contraction of the ankle plantar and dorsiflexors in many subjects. In addition to providing feedback on TA bEMG activity so that subjects could avoid co-contraction, the delivery of stimuli was avoided if more than a slight co-contraction was being observed. Nevertheless, in some of the tandem stance measures, the TA bEMG level was higher than that typically observed during the stable stance. To ensure that the contraction of the TA was similar across the data used to compare the two stances, to take care that reciprocal inhibition was not changing (Maluf et al., 2007; Richard B. Stein, Estabrooks, McGie, Roth, & Jones, 2007), the following procedure was used to eliminate samples taken when the TA bEMG activity was elevated. In all subjects the TA bEMG activity was low and consistent in the stable stance position. For each subject’s tandem stance data, stimuli were omitted from analysis if the TA bEMG activity was greater than two standard deviations above the mean TA bEMG activity for the same subject’s stable stance position (Solopova et al., 2003). If this did not result in a difference of less than 10% in mean TA bEMG activity for the two stance positions, then trials with the greatest TA bEMG activity were successively omitted, until a difference of 10% or less was obtained (Tokuno et al., 2009).
For each subject the peak-to-peak amplitude of the T-reflex EMG responses and the corresponding soleus bEMG levels were plotted for each of the stance positions (Figure 2). Soleus T-reflex amplitude was compared across the two stances within each subject at a similar level of motoneuron excitability, the latter reflected by the soleus bEMG level (Bove, Trompetto, Abbruzzese, & Schieppati, 2006; Kearney, Lortie, & Stein, 1999; Maluf et al., 2007; Matre, Sinkjaer, Knardahl, Andersen, & Arendt-Nielsen, 1999; Simonsen, Dyhre-Poulsen, & Voigt, 1995; Sinkjaer et al., 1996). The soleus bEMG activity range that was common to both of the stance positions tested in a subject was used to limit which measures of reflex amplitude were used for comparison across the two stances (between vertical bars in Figure 2), data points outside this common range were excluded from calculations. The soleus T-reflex amplitude observations within the range of common soleus bEMG activity were averaged, for each of the stance positions.

To determine if the mean T-reflex amplitude, soleus bEMG activity and TA bEMG activity within an individual were different when comparing the stable and tandem stance positions, the measure in the tandem stance position was expressed as a percentage change from the measure observed in the stable stance position in the same individual. The percentage change in each measure occurring with the change to the tandem stance for each subject was then averaged across subjects to produce a mean within subject change in T-reflex amplitude, soleus bEMG activity and TA bEMG activity when comparing the stable and tandem stance positions. This data analysis approach prevented intersubject differences in absolute or normalized T-reflex amplitude from obscuring
intrasubject changes in amplitude with a change in stance position, as may occur if
averages were determined across subjects for each stance position before body
position averages were compared.

Statistical Analyses

Two-tailed single-sample t-tests were used to determine if the percent change
between the stable and tandem stance position was significantly different from
zero, for the T-reflex amplitude, soleus bEMG activity and TA bEMG activity.
Statistical analysis was carried out for all subjects, and for both the subgroups of
subjects who could, and could not, perform the tandem stance without touching
the support boxes. The alpha level for each of these nine tests was adjusted with
the Bonferroni adjustment (i.e., 0.05/9 = 0.0056) (Vincent, 1999), and analysis was
carried out using SPSS (version 17, SPSS Inc., Chicago, Il). Results are reported
as mean (standard deviation). To determine the practical significance of the
results, Cohen's $d$ was calculated for comparisons that were statistically significant
(Faul, Erdfelder, Lang, & Buchner, 2007; Hatcher, 2003).

Results

Fourteen of 19 subjects decreased mean T-reflex amplitude when in the
tandem stance position, compared to the stable stance, with a mean decrease of
13.7% (31%) (table 1, figure 3). Nine of the nineteen subjects were able to perform
the tandem stance without touching the support boxes. All of these subjects
decreased their T-reflex amplitude when in the tandem stance position, compared
to the stable stance (table 1, figure 3). Their -31% (20%) mean decrease in reflex
amplitude was statistically significantly different from zero change ($p = 0.002$), and
the change was classified as large based on the Cohen's d value of 1.5 (Vincent,
1999). For the 10 subjects who needed to lightly touch the support boxes with the
back of two or three fingers while performing the tandem stance, a greater
variability in their T-reflex amplitude change was observed. Half of these subjects
decreased reflex amplitude while the others increased reflex amplitude, resulting
in a mean change of 2.0% (32%). For all subjects, and for the subgroups of those
that could, or could not perform the tandem stance without touching support
boxes, there was no significant change in soleus or TA bEMG levels (table 1,
figure 3).

**Discussion**

This study has shown that when subjects reduced the width of their standing
base of support, to make the standing task more difficult, most (14 of 19) reduced
the amplitude of their T-reflex, compared to the amplitude when in a stable wide
stance position. The reduction in T-reflex amplitude was statistically significant and
large (Cohen’s d interpretation) for subjects that could perform the tandem stance
without finger touch support. This reduction in T-reflex amplitude is consistent with
the idea that during a challenging motor task, Ia afferent mediated reflex size may
be reduced to prevent the spindle Ia signal from being strong enough to
excessively activate spinal motor neurons (Hayashi et al., 1992; Hidler & Rymer,
1999; Llewellyn et al., 1990; V. G. Macefield et al., 1993; McIlroy et al., 2003;
Taube et al., 2007). Some portion of the reduced soleus T-reflex observed during
the tandem stance may be due to an increased anxiety associated with the task,
as opposed to the motor challenge, per se. When anxiety was increased while maintaining a simple standing posture, by having subjects stand at the edge of an elevated platform, H-reflex amplitude was reduced compared to a low platform condition, and the reduction was not strongly related to a reduced soleus bEMG activity concurrently observed (Sibley et al., 2007).

Within subjects, the amplitude of the T-reflex did not show a consistent pattern of increasing as the bEMG level of the stretched muscle increased (Figure 2), as has been observed in some other studies (Pruszynski, Kurtzer, Lillicrap, & Scott, 2009; R. B. Stein, Hunter, Lafontaine, & Jones, 1995; Toft, Sinkjaer, & Andreassen, 1989). This may be explained by the observations of Blackburn and coworkers, which showed that soleus stretch reflex amplitude was not related to soleus bEMG level, when the bEMG varied over a small 13 ± 7% range of the maximum voluntary contraction (MVC) level (Blackburn, Mynark, Padua, & Guskiewicz, 2006). The range of soleus bEMG examined in the present study was much smaller than 13% of the subject’s MVC level, only slight contractions above that needed to maintain stance were produced by the subjects.

The correction of lateral instability during single legged stance can involve hip corrective strategies (Gribble & Hertel, 2004), when the ankle corrections are unable to maintain control (Tropp & Odenrick, 1988). In the present study the subjects were instructed to maintain postural control by their ankle musculature. Instability that involved hip movement was considered excessive and the subjects were required to limit movement to their ankles, and stabilized themselves by light finger touch, if needed. For the control of inversion and eversion movements of the
ankle, the triceps surae plays a functional role in humans (Klein, Mattys, & Rooze, 1996).

Subjects who needed to lightly touch adjacent support boxes to be able to steadily maintain the tandem stance position, exhibited either a moderate decrease or an increase in T-reflex amplitude compared to stable stance. All of the subjects that increased their T-reflex amplitude compared to stable stance were ones that required the light touch of the boxes. Previous studies indicate that haptic stabilization by finger touch diminishes the reduction in H-reflex amplitude seen when standing, or standing on one foot, and that the effect is greatest when lateral touch, such as used in the current study, is employed (Hayashi et al., 1992; Huang et al., 2009). Accordingly, for the subjects that required a light finger touch during the tandem stance, it is may be that their T-reflex would have been smaller in the tandem stance position, if they could have maintained a stable tandem stance without finger touch. This haptic stabilization may have contributed to the increase in T-reflex amplitude seen in five subjects in the tandem stance position, despite the subjects reporting, and the researcher observing, that the tandem stance position was still very difficult. Alternately, for some difficult skills, or perhaps for some people performing those difficult skills, an increase in stretch reflex amplitude may be more appropriate for the task. Nafati and coworkers demonstrated that during an attention demanding wrist extensor muscle motor task the T-reflex was facilitated (Nafati et al., 2004). Similarly, hand muscle studies have found that during a position control task, the stretch reflex response is
increased compared to a force control task at the same force level (Akazawa, Milner, & Stein, 1983; Kanosue, Akazawa, & Fujii, 1983).

**Mechanism of reflex amplitude modulation**

The amplitude of the soleus stretch reflex may be modulated in the spinal cord. This was demonstrated by Burke and coworkers who showed that changes in Achilles tendon jerk reflex amplitude could be modified by conditions such as distraction, discomfort, attention changes, rate of tendon percussion or distant muscle contraction, while these conditions did not modify the afferent response to muscle stretch (Burke, McKeon, & Skuse, 1981).

For the soleus H-reflex, produced by electrical stimulation of afferent axons in the posterior tibial nerve, the reflex modulation that occurs between standing tasks of different difficulties is likely due to changes in presynaptic inhibition of the Ia afferent signal between the tasks (Angulo-Kinzler, Mynark, & Koceja, 1998; Capaday & Stein, 1987; Edamura, Yang, & Stein, 1991; Faist, Dietz, & Pierrot-Deseilligny, 1996; Hayashi et al., 1992; Katz et al., 1988; M.H. Trimble, 1998).

This assumes the tasks examined have comparable alpha motoneuron excitability (R. Stein & Kearney, 1995) (reflected by background EMG), reciprocal inhibition (Crone & Nielsen, 1989) (reflected by antagonist EMG), and that the frequency of afferent activity does not produce homosynaptic post activation depression in the Ia afferents (Hultborn et al., 1996). In the current study, the interval between stimuli avoided homosynaptic depression (Grey et al., 2008; Pierrot-Deseilligny & Mazevet, 2000). Additionally, changes in the T-reflex amplitude in the tandem
stance, compared to the stable stance, cannot be attributed to changes in soleus or TA muscle activity. As a group, there was no significant change in the soleus or TA bEMG levels when performing the tandem stance compared to the stable stance (table 1). Additionally, the correlation between the mean change in T-reflex amplitude and mean change in soleus bEMG level for subjects was negligible ($r=0.04$). While a very weak correlation between individuals' mean change in T-reflex amplitude and mean change in TA bEMG level was found ($r=0.33$), its positive value is the opposite one would expect if an increase in TA activation in the tandem stance position were a factor, via reciprocal inhibition, to produce the decreased T-reflex amplitude observed in most individuals (Crone & Nielsen, 1989). Cutaneous, and non-spindle proprioceptive influences on the spinal networks are not expected to change between the two stance positions examined, and so are unlikely to explain the reduced T-reflex amplitude observed. Similarly, soleus stretch amplitude and velocity, stimuli to muscle spindles (Dimitriou & Edin, 2008; R. Stein & Kearney, 1995), are assumed to be the same for the two stance positions, based on the unchanged right ankle position and soleus muscle activation levels for the two positions, and the demonstrated consistency of the striking force. There is, however, the possibility that activity of other muscles controlling medial and lateral ankle movement could have changed during the tandem stance task, and this could have affected the soleus motoneurons. Additionally, reflex modulation through poly synaptic connections between Ia afferents and alpha motor neurons could occur, although this would be observed
at slightly later times than the monosynaptic response (Jankowska, 1992; Ludvig, Cathers, & Kearney, 2007).

The amplitude of stretch reflex, may also be modulated by changes in the mechanical sensitivity of the muscle spindles (Naoyuki Kakuda & Nagaoka, 1998). In cats, static and dynamic gamma drive to spindles and Ia sensitivity was elevated during novel exploratory and difficult beam walking tasks (Hulliger, 1993; Prochazka, Hulliger, Trend, & Durmuller, 1988). In humans, the Ia signal is similarly enhanced during challenging tasks, although whether this can occur by fusimotor activation without concurrent extrafusal activation is debated. During precision finger movements, fusimotor activity and the firing rates of spindle afferents was increased, although in most cases skeletomotor activity was elevated as well, indicating that fusimotor activity was not controlled independently of skeletomotor activity (N. Kakuda, Vallbo, & Wessberg, 1996; N. Kakuda, Wessberg, & Vallbo, 1997). Similarly, during a standing balance task that required increased muscle activation, pretibial muscle fusimotor drive was increased to affect spindle discharge (Aniss, Diener, Hore, Burke, & Gandevia, 1990). In contrast, during an attention and accuracy demanding motor task, the tendon reflex of wrist extensor muscles was enhanced, with no change in muscle activity, suggesting enhanced fusimotor spindle sensitization (Nafati et al., 2004). Similarly, selective enhancement of fusimotor drive to increase spindle sensitivity was suggested by Hospod and coworkers (Hospod, Aimonetti, Roll, & Ribot-Ciscar, 2007) to explain enhanced limb movement pattern recognition during an attentional test. Likewise, during unsupported stance, low threshold cutaneous and
muscle afferents from mechanoreceptors in the human foot appear able to reflexly activate fusimotor neurons innervating pretibial flexor muscles (Aniss et al., 1990). The potential for a possible increased muscle sympathetic drive during the tandem stance to alter spindle sensitivity is unclear, based on contrasting experimental results (Hjortskov, Skotte, Hye-Knudsen, & Fallentin, 2005; Kamibayashi et al., 2008; V. G. Macefield, Sverrisdottir, & Wallin, 2003).

In sum, the current results can not establish the mechanism of the modulation in T-reflex amplitude when subjects shifted to the tandem stance position. The soleus H-reflex data showing an increase in presynaptic inhibition of the Ia afferent signal acting on soleus motor neurons when standing without support (Katz et al., 1988) suggest that an increase in presynaptic inhibition may have played a role in the decreased T-reflex amplitude observed in most subjects in the tandem stance position. The T-reflex, however, is less depressed by presynaptic inhibition than the H-reflex is (Enriquez-Denton et al., 2002; Morita, Petersen, Christensen, Sinkjaer, & Nielsen, 1998). Previous studies discussed above suggest that the Ia afferent signal may be greater in the difficult tandem stance, again suggestive that the presynaptic inhibition acting on the Ia afferent signal would need to increase to produce a net decrease T-reflex amplitude in the tandem stance position. No change, or a decrease, in the Ia afferent signal in the tandem stance position, however, cannot be ruled out.

Comparison to H-reflex studies
It is interesting to compare the T-reflex modulation when changing between a stable and tandem stance position, found in the present study, with the H-reflex modulation observed in similarly aged subjects for the same two motor skills previously (G. R. Chalmers & Knutzen, 2002). In both studies, most subjects decreased reflex amplitude when in the unstable tandem stance position, while a few subjects increased reflex amplitude (Figure 3), and the range of changes were similar, although smaller in the H-reflex study that included fewer subjects. If it were known that the subjects that greatly decreased T-reflex amplitude also greatly decreased H-reflex amplitude, and visa-versa, then it would be suggestive of an important role of presynaptic inhibition in modulating T-reflex amplitude across the stance positions, based on the evidence that H-reflex modulation between standing tasks of different difficulties is likely due to changes in presynaptic inhibition of the Ia afferent signal between the tasks (Katz et al., 1988).

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Conflict of Interest

There are no conflicts of interest associated with this work. There are no study sponsors.
References


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Table 1: Changes in mean T-reflex amplitude, soleus bEMG activity and TA bEMG activity when subjects performed a tandem stance, compared to stable stance.

Results are reported as mean (standard deviation). * Significantly different from zero change (p = 0.002).

<table>
<thead>
<tr>
<th></th>
<th>T-reflex amplitude</th>
<th>Soleus bEMG activity</th>
<th>TA bEMG activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subjects (n=19)</td>
<td>-13.7%</td>
<td>-2.7%</td>
<td>0.3%</td>
</tr>
<tr>
<td></td>
<td>(31%)</td>
<td>(9%)</td>
<td>(6%)</td>
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<tr>
<td>Subjects who could perform the tandem</td>
<td>-31.2%</td>
<td>-3.7%</td>
<td>-2.4%</td>
</tr>
<tr>
<td>stance without lightly touching</td>
<td>(20%)*</td>
<td>(9%)</td>
<td>(6%)</td>
</tr>
<tr>
<td>support boxes (n=9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects who needed to lightly touch</td>
<td>2.0%</td>
<td>-2.0%</td>
<td>2.8%</td>
</tr>
<tr>
<td>support boxes while performing the</td>
<td>(32%)</td>
<td>(10%)</td>
<td>(5%)</td>
</tr>
<tr>
<td>tandem stance (n=10)</td>
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Figure 1: T-reflex EMG responses for a single subject in the stable stance (solid line) and tandem stance (dashed line) positions. These two data samples are representative examples from the subject illustrated in figure 2B who demonstrated a 16% decrease in mean T-reflex amplitude when tandem stance measures were compared to stable stance measures. Tendon tap occurred at time zero (vertical dotted line).

Figure 2: T-reflex amplitude versus soleus bEMG plots for subjects who demonstrated an increase (A, +49%), or decrease (B, -16%; C, -63%) in mean T-reflex amplitude when tandem stance measures (triangles) were compared to stable stance measures (boxes). Only measures within the range of soleus bEMG that was common to both stance positions, between vertical bars, were used to calculate mean reflex amplitude for the position. Horizontal bars identify the mean T-reflex amplitude of the stable stance (solid line) and tandem stance (dashed line) data between the vertical bars.
Figure 3: Changes in mean T-reflex amplitude, soleus bEMG activity and TA bEMG activity when subjects performed a tandem stance, compared to stable stance. Nine of the nineteen subjects were able to perform the tandem stance with hands near their sides (circles), while ten subjects needed to lightly touch the vertical sides of adjacent support boxes with the back of two or three fingers while performing the tandem stance (crosses). For comparison purposes, data from a previous study (G. R. Chalmers & Knutzen, 2002) is included showing change in H-reflex amplitude when performing a tandem stance compared to a stable stance (diamonds).